



**DOES SEQUENTIAL HARVESTING AFFECT THE QUALITY OF AND
INCOME FROM ORGANICALLY GROWN POTATOES?**

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ABSTRACT

Lack of effective storage facilities to mitigate post harvest losses threatens the profitability of organic farming. In rural KwaZulu-Natal, small scale farmers use traditional storage and sequential harvesting to keep potatoes post maturity while waiting to sell. The effect of these practices on potato quality has not been studied and documented. This study set out to investigate if traditional practices (sequential harvesting and traditional farmer's store) of the Ezemvelo Farmers Organisation in Umbumbulu affect the quality and marketable quantity of organically grown potatoes. Specifically the study set to investigate the effect of traditional farmer's store, *in situ* and controlled storage on the carbohydrate content and sensory quality of potatoes organically grown in Embo by EFO farmers; determine consumer quality expectations of organically and conventionally grown potatoes; investigate the effect of sequential harvesting on the potato quality expectations of consumers and to investigate the produce and income losses experienced by small scale organic farmers at harvest and during storage.

Experiments were conducted to compare the effect of sequential harvesting, farmer's store and controlled cold storage (7°C and 90% relative humidity) on the sensory, appearance and keeping quality of organically grown potatoes. A survey of 100 consumers (40 organic and 60 conventional consumers) was conducted to ascertain consumer appearance and keeping quality expectations of potatoes. In addition, a survey of 101 farmers investigated the storage practices of the EFO farmers who grew potatoes and the type of losses incurred in storage. Preference ranking was used to investigate if time of harvesting post maturity affected potato quality. Produce losses experienced by the farmers were quantified. A co-research group of three seasoned farmers of the EFO participated in the research. They produced potatoes used in the study and provided valuable input to ensure that the study adhered to storage practices of the farmers.

The lowest and highest sugar levels were observed in potatoes stored *in situ* and under controlled conditions, respectively. Potatoes left *in situ* also recorded higher starch content. Potatoes stored *in situ* were significantly preferred by sensory panellists

($p < 0.05$) over those stored in both farmer's store and in controlled storage. Preference rank scores were negatively correlated to total sugar content and positively correlated to starch content.

Consumers in the study highlighted five desirable appearance qualities in potatoes: absence of greening, absence of sprouting, smooth skin texture, absence of blemishes and light skin colour. No significant differences in the quality expectations between participating organic and conventional potato consumers were found. The majority of consumers expected potatoes to store for at least three weeks post purchase. Sequentially harvested potatoes met this expectation when potatoes were left *in situ* for a maximum of six weeks post maturity. Potatoes *in situ* also maintained good appearance and sensory quality.

The highest produce losses were experienced in summer owing to soft rot problems. Production in the drier seasons (autumn and winter) increased the proportions of potatoes too small to be sold as table potatoes. With the exception of completely rotten potatoes, poor quality potatoes were consumed, used as seed potatoes and sold to the local market as seed and for food. Poor potato quality resulted in reduced income for the farmers.

This investigation pioneered research into the effect of sequential harvesting on the quality of organically grown potatoes. The findings demonstrate that sequential harvesting provides resource-poor small scale organic farmers with an efficient storage option where other storage methods and technologies may be inappropriate, ineffective or unaffordable.

It is recommended that government and other players in the agricultural sector plan initiatives to educate small scale potato farmers on the benefits of sequential harvesting as an effective short term method of potato storage. Research with other potato cultivars in different agro-ecological settings is needed to optimise sequential harvesting. Government policy aimed at training and developing farmer capacity in organic seed potatoes production is essential to ensure that farmers access disease and pest free seed. Farmers also need assistance to access to irrigation resources to improve production.

DECLARATION

I, **Mangani George Chilala Katundu**, declare that:

The research reported in this thesis, except where otherwise indicated, is my original research.

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As Research Supervisor, I agree to submission of this thesis for examination.

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As Research Co-supervisor, I agree to submission of this thesis for examination.

Signed: Date

Name: Mr. Muthulisi Siwela

DEDICATION

To my great friends Atikonda, George and Nehemiah Katundu

and

for the love of potatoes

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TABLE OF CONTENTS

ABSTRACT	ii
DEDICATION.....	v
ACKNOWLEDGEMENTS.....	vi
TABLE OF CONTENTS.....	viii
LIST OF FIGURES	x
LIST OF TABLES.....	xi
ABBREVIATIONS AND ACRONYMS	xiii
CHAPTER 1: STATEMENT OF THE PROBLEM.....	1
1.1 Introduction.....	1
1.2 Problem statement.....	3
1.3 Sub problems	3
1.4 Study limits and general assumptions.....	3
1.5 Outline of the thesis	4
References	4
CHAPTER 2: LITERATURE REVIEW	7
2.1 Organic production: opportunities and constraints for small scale farmers	7
2.1.1 Opportunities in organic production for small scale farmers.....	7
2.1.2 Constraints facing small scale organic producers.....	8
2.2 Organic produce consumers and their expectations.....	12
2.3 Importance of potatoes as a food and cash crop	13
2.4 What constitutes potato quality?.....	14
2.4.1 Potatoes sensory characteristics.....	14
2.4.2 Potato Greening	19
2.4.3 Potato sprouting and dormancy	19
2.4.4 Potato tuber diseases and pests	23
2.5 Summary	23
References	24
CHAPTER 3: DESCRIPTION OF THE STUDY AREA AND EFO.....	37
3.1 Location of the Ezemvelo Farmers Organisation	37
3.2 Description of the EFO	38
3.3 Marketing of EFO organic produce	40
References	41
CHAPTER 4: EFFECT OF TRADITIONAL STORAGE PRACTICES OF SMALL SCALE ORGANIC FARMERS ON POTATO QUALITY.....	43
4.1 Introduction.....	43
4.2 Research methodology.....	44
4.2.1 Carbohydrate content analysis	45
4.2.2 Sensory evaluation	47
4.3 Data analysis	47
4.4 Results and discussion	48
4.4.1 Carbohydrate content of potatoes	48
4.4.2 Sensory preference of potatoes	50
4.5 Conclusions.....	52
References	53

CHAPTER 5: CAN SEQUENTIAL HARVESTING HELP SMALL HOLDER ORGANIC FARMERS MEET CONSUMER EXPECTATIONS FOR ORGANIC POTATOES?	57
5.1 Introduction	57
5.2 Research methodology	58
5.3 Data analysis	61
5.4 Results and discussion	61
5.4.1 Consumer and supermarket quality expectations	61
5.4.2 Farmer storage practices	63
5.4.3 Effect of storage on potato quality loss.....	64
5.4.4 Effect of sequential harvesting on potato dormancy.....	66
5.4.5 Effect of sequential harvesting on sensory qualities of potatoes	66
5.4.6 Can sequential harvesting help smallholder organic farmers meet consumer expectations for organic potatoes?	67
5.5 Conclusion	69
References	69
CHAPTER 6: DOES QUALITY LOSS IN STORAGE RESULT IN SIGNIFICANT REVENUE LOSS FOR SMALL SCALE ORGANIC FARMERS? ..	74
6.1 Introduction	74
6.2 Research methodology	75
6.2.1 Determination of weight losses in storage	75
6.3 Data analysis	78
6.4 Results and discussion	79
6.4.1 Farmer production practices	79
6.4.2 Causes of produce losses as identified by farmers.....	80
6.4.3 Losses in storage as determined experimentally.....	80
6.4.4 Does loss of quality mean income loss?	86
6.4.5 Does sequential harvesting and storing potatoes help farmers get better prices for their potatoes?	88
6.5 Conclusion	88
References	89
CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS	93
7.1 Findings and conclusions	93
7.2 Recommendations	96
7.3 Recommendations for further studies	98
APPENDIX 1 : QUESTIONNAIRE FOR PREFERENCE TEST- RANKING	99
APPENDIX 2 : PANELLIST CONSENT FORM FOR PARTICIPATION IN THE SENSORY EVALUATION EXERCISE	100
APPENDIX 3: ETHICAL CLEARANCE NOTIFICATION FROM THE UNIVERSITY OF KWAZULU-NATAL FOR THE USE OF HUMAN SUBJECTS IN THE SENSORY EVALUATION OF POTATOES	102
APPENDIX 4: PART OF THE EFO SURVEY QUESTIONNAIRE 2004.....	103

LIST OF FIGURES

Figure 2.1: Map of Africa showing the area under organic agriculture (Parrot <i>et al.</i> , 2006).	9
Figure 3.1: Map of Durban and the surrounding areas showing the location of Embo, the study site. http://www.kzn.org.za/travelguidemaps/Durban.gif [accessed on 20 November 2007]	37
Figure 4.1: Soil and ambient temperature patterns where potatoes were left in situ and in the farmer's storage respectively for the seasons a) summer, b) autumn and c) in winter	46
Figure 5.1: Effect of harvesting time on the sensory quality of potatoes as shown by preference ranking scores.	67
Figure 6.1: Scale used to classify potatoes of unacceptable quality due to greening (Grunenfelder, Hiller, and Knowles, p 76, 2006).	76
Figure 6.2: Mist extraction of nematodes from plant tissue (Shivas <i>et al.</i> , p 38, 2003)	78
Figure 6.3: Millipede: a potato pest observed during the experiment	81

LIST OF TABLES

Table 2.1. An example of preference ranking results	18
Table 2.2. Testing the significance of differences in preference rank sums using Basker's critical difference value.....	18
Table 4.1. Total sugar and starch content (g kg^{-1} , dry weight basis) of an organically grown landrace potato cultivar from three seasons left <i>in situ</i> , and stored in a farmer's store and in a controlled environment (7°C and 90% RH) over 2, 4 and 6 weeks	49
Table 4.2. Percentage of samples from <i>in situ</i> , farmer and controlled storage ranked either most preferred (1) or both most (1) and second most preferred (2) by panellists	50
Table 4.3. Pearson's correlation coefficients between total sensory preference score and levels of sugars and starch in organically produced potatoes.	51
Table 5.1: Appearance quality attributes used by potato consumers when purchasing potatoes.....	62
Table 5.2: Consumer expectation of the storage life of organic and conventional potatoes	62
Table 5.3: Potato quality expectations of the supermarket to which the farmers sell	63
Table 5.4: Association between reported storage problems experienced by small scale organic potato farmers and practice of sequential harvesting using chi-square tests.....	64
Table 5.5: Effect of sequential harvesting and storage in farmer's store on potato losses due to quality deterioration in Embo.....	65
Table 5.6: Effect of time of harvesting sequential harvesting on potato dormancy	66
Table 6.1: Comparison of storage problems reported by farmers who did and those did not practise sequential harvesting (Embo, November 2004).....	80
Table 6.2: Percentage losses due to different types of quality deterioration in organically grown landrace potato cultivar from three seasons left <i>in situ</i> , and stored in a farmer's store and in a controlled environment (7°C and 90% RH) over 2, 4 and 6 weeks	83

Table 6.3: Correlations between different forms of losses, season, method and length of storage.....	84
Table 6.4: Potato weight loss due to desiccation of organically grown landrace potatoes when stored in a farmer’s store and in a controlled storage over 2, 4 and 6 weeks.....	85
Table 6.5: Proportions of smaller and bigger potatoes baby potatoes sold by EFO farmers to the organic niche market expressed as a percentage of total potatoes harvested in summer, autumn and winter.....	86
Table 6.6: Monetary value of produce losses	87

ABBREVIATIONS AND ACRONYMS

AFRISCO	African Farms Certified Organic
AOAC	Association of Official Analytical Chemists
EFO	Ezemvelo Farmers Organisation
FAO	Food and Agriculture Organisation
HPLC	High Performance Liquid Chromatography
IFOAM	International Federation of Organic Agriculture Movements

CHAPTER 1: STATEMENT OF THE PROBLEM

1.1 Introduction

Improving the income for small scale farmers is a powerful factor in reducing poverty and food insecurity (Bressciani and Valdés, 2007; Kirsten *et al*, 2007). Organic agriculture is defined as farming methods that exclude application of synthetic fertilizers and pesticides (Rundgren, 2004). Certified organic produce fetch premium prices and provide an opportunity for small scale farmers to increase incomes (Gifford and Benard, 2006; Hellin and Higman 2002). South African subsistence farmers, like those of the Ezemvelo Farmers Organisation (EFO) who traditionally practice organic farming (Modi, 2003) could be strategically poised to benefit from this market if constraints to production and marketing were resolved. In the absence of advanced storage facilities, it is not known whether such farmers could ensure supply of quality produce to meet market expectations.

Due to the exclusion of synthetic chemicals, organic farmers are faced with challenges of preserving produce quality and minimising post harvest losses of perishable horticultural products. This problem is more pronounced for small scale farmers in rural areas who are far from markets and are without reliable means to transport produce to markets at maturity. While waiting for opportunities to supply, farmers risk produce losses due to quality deterioration. Research aimed at identifying appropriate storage techniques that minimise quality losses is essential.

The EFO is a group of traditional organic farmers in the Umbumbulu District in KwaZulu-Natal. The group attained organic certification in 2002, becoming the first group of small scale farmers to gain certification in South Africa (Ndokweni, 2002). Baby potatoes rank second as a cash crop for the farmers (Ndokweni, 2002). The potatoes are supplied to a supermarket chain through a pack house, in quotas, on demand (Ndokweni, 2002). Due to scarcity of and the high cost of transporting produce to other markets the farmers wait for demand from the pack house to sell their produce at premium prices and to fulfil contractual agreements.

Potatoes are stored in a fully hydrated, highly perishable form (Suttle, 2004). Quality losses in storage are caused by microbiological, physiological and environmental factors (Burton *et al*, 1992; Dahiya *et al*, 1997; Suttle, 2004; Sparenberg, 1987). Storage is especially difficult for small scale organic farmers who do not have the requisite facilities and technologies to reduce post harvest losses. To mitigate this loss, some small scale farmers leave potatoes *in situ*; harvesting the remaining crop sequentially as and when needed (Mankhanya, Wanda and Ngcobo, 2004). The effect of leaving potatoes *in situ* post maturity on potato quality has not been fully studied and documented.

Potatoes left *in situ* are subject to damage by pests such as millipedes, rodents and diseases. A number of studies in different areas have looked at effects of leaving potatoes *in situ* for varying durations. In the Philippines potatoes left *in situ* for up to three months experienced minimal losses (6%) (de los Santos *et al* 1986). In Greece a study of three commercially produced potato varieties left *in situ* for three months in winter showed that the dry matter content did not change while reducing sugar levels increased (Dogras, Siomos and Psomakelis 1991). However, these two studies did not investigate the shelf life and sensory qualities of potatoes harvested at different times post maturity or studied potatoes left *in situ* in seasons other than winter.

Bruinsma and Swart (1970) reported that the later the potatoes are harvested after maturity, the shorter the period of dormancy and hence reduced shelf life. The shelf life expectations of South African consumers of organically grown potatoes are not known. Research aimed at understanding the perceptions and needs of target consumer for any product is essential (Kilcast, 2006). The studies stated above and in preceding paragraphs did not investigate the effect of sequential harvesting on the quality of organically grown potatoes in general and in the South African context in particular.

Kirkwood (2005) noted that potato quality changes *in situ* over extended periods of time depended on the cultivar, production location and soil type. French (1981) noted that cultivar influenced the quality characteristics of potatoes and Kaaber *et al* (2001) reported that storage conditions affect the chemical content (in particular carbohydrate composition) and sensory characteristics of potatoes. Investigations aimed at helping

South African organic farmers establish how long they can sequentially harvest potatoes and still meet consumer quality expectations is needed to increase returns from investment and increase household incomes.

1.2 Problem statement

To investigate how traditional storage practices (sequential harvesting or *in situ* storage and farmer's store) of the EFO in Umbumbulu affect the quality and marketable quantity of organically grown potatoes.

1.3 Sub problems

To address the problem in section 1.2, the following four sub problems were investigated.

Sub problem 1. To investigate the effect of traditional farmer's store, *in situ* and controlled storage on the carbohydrate content and sensory quality of potatoes organically grown in Umbumbulu by EFO farmers.

Sub problem 2. To determine consumer quality expectations of organically and conventionally grown potatoes.

Sub problem 3. To investigate the effect of sequential harvesting on the consumer potato quality expectations.

Sub problem 4. Investigate the produce and income losses experienced by small scale organic farmers during harvesting and storage.

1.4 Study limits and general assumptions

With the exception of cold storage which was carried out at the University of KwaZulu-Natal in Pietermaritzburg, this study was done in one site at Embo in the Umbumbulu district of KwaZulu-Natal, South Africa. The storage experiments investigated organically grown potatoes and no comparisons were made between organically and conventionally grown potatoes. Three seasoned, certified small scale organic farmers of the EFO produced the potatoes used in the experiments. It is assumed that their production practices reflected the general production practices of the EFO farmers.

The consumer survey was conducted in Pietermaritzburg, at an agricultural show by people who would fall within an immediate market for the EFO farmers. It is assumed that the potato consumers who attended the show were representative of organic buyers in the region. Assumption relevant to specific sub problems are explained in relevant sections that follow.

1.5 Outline of the thesis

Chapter one presents the background to the problem and sub-problems investigated in this research. Chapter two reviews literature on organic farming, the opportunities and challenges of organic farming for small scale farmers and consumer expectations of organic produce. The importance of potato as a food and cash crop and factors that affect potato quality are also discussed. Reference is made to the challenges that organic farmers may face in trying to maintain desirable potato quality characteristics. Chapter three presents an overview of the Ezemvelo Farmers organisation, a brief description of the study area and general demographic characteristics of the farmers of the EFO.

The three chapters that follow present papers that cover the four sub problems of this study. Chapter four presents results of the investigation on the effect of traditional farmer's store, *in situ* and controlled storage on the carbohydrate content and sensory quality of potatoes organically grown in Embo. Chapter five presents results of an investigation into the consumer quality expectations of potatoes and the effects of sequential harvesting on the potato keeping quality expectations of consumers. Chapter six presents results of an investigation into the produce and income losses experienced by small scale organic farmers at harvest and during storage resulting from quality deterioration. Conclusions and recommendations are presented in chapter seven.

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CHAPTER 2: LITERATURE REVIEW

2.1 Organic production: opportunities and constraints for small scale farmers

According to Kuepper and Gegner (2004, p2) organic farming is defined as “an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony.” Organic agriculture excludes the use of synthetic pesticides, conventional fertilisers, pharmaceuticals and by definition excludes genetically modified plants and animals (Chen, 2007; Dreezens *et al*, 2005; Roitner-Schobesberger *et al*, 2008; Rundgren, 2004). Organic farming presents an opportunity for small scale farmers to increase income and production through participation in lucrative organic markets and current interest in and support for environmentally friendly production systems. However, there are also constraints that limit the growth and effective participation of small scale organic farmers in the formal market. Research aimed at mitigating the effects of these constraints is vital for the success of organic farming as a livelihood strategy for small scale farmers. The opportunities and constraints facing small scale organic farmers are discussed in two subsections below.

2.1.1 Opportunities in organic production for small scale farmers

Organic farming is one of the fastest growing niche markets for food (Chen, 2007; Gifford and Bernard, 2006; Modi, 2003). The rapid growth of organic farming is evident in that it is now practiced in approximately 120 countries of the world and its share of agricultural land and farms continues to grow (Siderer, Maquet and Anklam, 2005; Wheeler, 2008; Yussefi, 2006). More than 31 million hectares are currently managed organically in at least 623,174 farms worldwide (Yussefi, 2006). The market for organic products is not only growing in Europe and North America (which are the major organic markets), but also in many other countries, including several developing countries like South Africa, Egypt, Kenya, Uganda and Tanzania (Parrot *et al*, 2006; Taylor, 2006). According to Darroch (2001) and Business Times (2004), there has been a growing interest in stocking of organic products by local

supermarket chains in South Africa. Similarly, the domestic market for organic produce is increasing in Kenya, Tanzania and Uganda (Taylor, 2006).

In Africa, there are two levels of organic farming: certified organic farming and non certified organic farming (Parrot *et al*, 2006). Parrot *et al* (2006) point out that certified organic farming is only a small portion of organic farming practiced on the continent. In South Africa, where approximately 45000 hectares (Figure 2.1.) are under organic cultivation, many subsistence farmers traditionally practice organic farming (Modi, 2003). Unlike where a farmer initially practised conventional farming, these small scale de-facto organic farmers already have the valuable skills and knowledge required for organic production (Rundgren, 2004 and Parrot *et al*, 2006). Milestad and Hadatsch (2003) reported that adoption and success in niche production systems is facilitated where farmers do not have to make major changes to their farms because their agricultural practices are similar to the system to be adopted.

It is evident that organic farming presents an opportunity for small scale farmers to scale up production and access higher prices for organic produce through organic niche markets (Gil, Gracia and Sanchez, 2000; Hellin and Higman, 2002; Yiridoe, Bonti-Ankomah and Martin, 2005; Taylor, 2006). Consequently civil society and both local and international governments have advocated for initiatives to lower the certification costs for small scale groups and development of government policies that regulate as well as facilitate the participation of small scale farmers in organic production (Taylor, 2006; Afrisco, 2007).

2.1.2 Constraints facing small scale organic producers

Although organic farming presents opportunities, small scale farmers face a number of constraints. Some of the constraints are the cost of certification, access to land for expansion; low productivity; shortage of inputs; and shortage of labour; lack of proper storage facilities; transport problems to markets; lack of agricultural extension support services and lack of knowledge of consumer expectations for their produce (Darroch and Mushayanyama 2006; Gadzikwa, Lyne and Hendriks 2006; Hellin and Higman, 2002; Ndokweni, 2002; Page and Slater, 2003; Thamaga-Chitja and Hendriks, 2007).

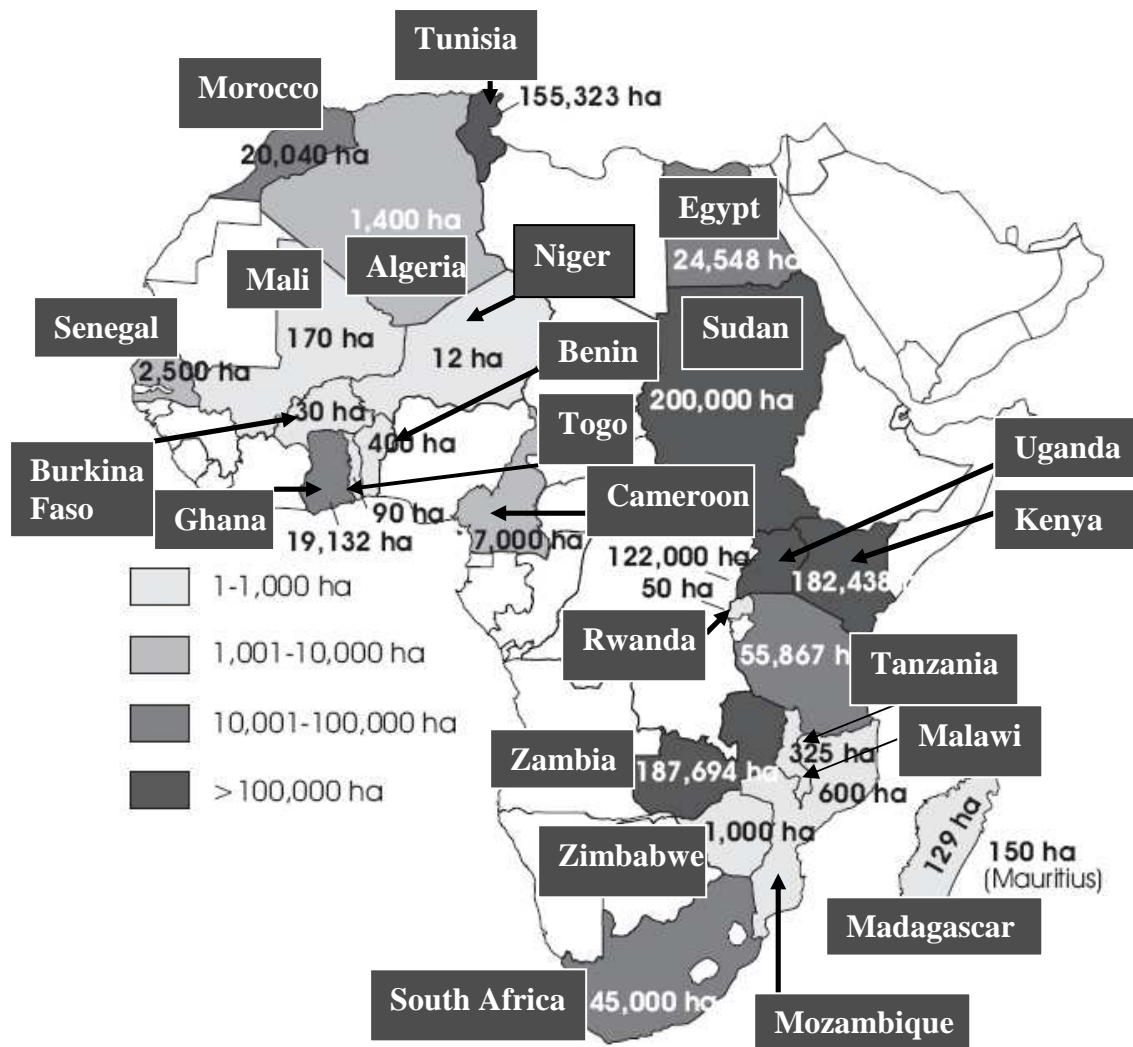


Figure 2.1: Map of Africa showing the area under organic agriculture (Parrot *et al*, 2006).

Organic agriculture is the most regulated form of agriculture as it adheres to legally defined standards and norms of production, processing, and labelling (Gadzikwa, Lyne and Hendriks, 2006). Farmers have to be certified as organic farmers to access organic markets and benefit from premium prices (Hellin and Higman, 2002). Apart from accessing markets, certification helps organic consumers distinguish between organic and conventional products and assures consumers that production and processing comply with specified standards (Siderer, Maquet and Anklam 2005).

Certification can be awarded to an individual or a group. Under group certification, organic farmers can either grow and market their produce collectively or produce individually but market collectively (Gadzikwa, Lyne and Hendriks, 2006). In either case the framers face recurrent annual certification costs and costs to cover expert

inspection visits necessary to retain their certification status. In recent years, Afrisco, an Ecocert certifying agent in South Africa, in conjunction with IFOAM (International Federation of Organic Agriculture Movements) have developed a programme to facilitate certification for small scale farmers called Internal Controls Systems. According to Afrisco (2007), the Internal Controls Systems aim to reduce the cost of organic certification by establishing a local group that can do much of the monitoring. The objective of the Internal Controls System is to carefully set up organic rules and regulations that are simplified so that even illiterate farmers understand the rules to follow and records to be kept.

Certification costs are a barrier to participation in organic niche markets for small scale farmers (Thamaga-Chitja and Hendriks, 2007). In South Africa, Government Departments and supermarket chain stores have helped small scale farmers meet certification costs (Gadzikwa, Lyne and Hendriks 2006). While this arrangement helps farmers in the short run, farmers still need to generate enough income to comfortably cover this cost when the subsidies end. To afford the certification costs, farmers need to increase income by scaling up production and reducing post harvest losses.

Traditionally, organic farms are small and labour intensive compared to extensive conventional farming (Kuepper and Gegner 2004; Taylor, 2006). Yields from organic farms have typically been lower than in conventional production (Trewavas, 2004). Maggio *et al* (2008) reported a 25% reduction in marketable yield of organically grown potatoes compared to conventionally grown potatoes of the same cultivars. Low yields and high labour and certification costs make organic production more costly compared to conventional production (Baecke *et al*, 2002; Rigby, Young and Burton, 2001; Trewavas, 2004). Organic produce prices are higher than prices for conventional produce and consumers are willing to pay premium prices for the produce (Yiridoe, Bonti-Ankomah and Martin, 2005). However, exorbitant prices may discourage consumers from buying organic products. Roitner-Schobesberger *et al* (2008) reported that in Thailand, where organic produce is priced as much as 50% more than conventional produce, the market share of organic products has remained relatively small. It is important for small scale organic farmers to keep transaction costs as low as possible to ensure competitively priced produce. Among other things,

this could be achieved by collective marketing (Gadzikwa, Lyne and Hendriks 2006; Ndokweni, 2002).

Individual small scale farmers may not produce enough to satisfy market demands. It has been reported that some small scale farmers pool produce in quotas depending on market demand and produce supply (Darroch and Mushayanyama 2006). Where contractual arrangements require exclusive supply to a single supermarket chain, farmers may not sell all their produce at maturity. Small scale producers who generally lack appropriate technologies to maintain quality may not meet supermarket produce quality expectations for suppliers (Berdegué *et al*, 2005; Biénabe and Sautier, 2005). Where farmers have access to supply supermarkets, quality deterioration post crop maturity and post harvest may rob farmers of profit. Consequently, farmers need appropriate storage technologies, especially for perishable produce to mitigate these losses (Eltawil, Samuel and Singhal, 2006).

Parrot *et al* (2006) reports that organic farming techniques have been researched by the World Agro Forestry Centre, the International Centre for Insect Physiology and Ecology and various universities. Research related to indigenous knowledge and the use of locally available resources to reduce post harvest losses is urgently needed to assist small scale producers (Parrot *et al*, 2006). There is need to involve farmers in the experiments and find innovative ways of disseminating research findings to farming communities to facilitate assimilation of recommended practices (Parrot *et al*, 2006 and Ashbey *et al*, 2000).

Page and Slater (2003) identified knowledge of and the capacity to meet externally imposed production, health and safety standards as a barrier for small scale farmers to access markets. Understanding consumer quality expectations in niche markets is necessary also because consumers may have different expectations and acceptance of the same food product produced using different technologies (Miraux *et al*, 2007). Page and Slater (2003) recommended that research aimed at helping farmers understand consumer expectations and finding innovative ways of preserving the desired quality attributes is essential.

2.2 Organic produce consumers and their expectations

Interest in organically produced food is increasing throughout the world in response to concerns about intensive agricultural practices and their potential effects on human health and the environment (Roitner-Schobesberger *et al*, 2008; Siderer, Maquet and Anklam, 2005). Research has shown that most organic consumers valued healthy and long lives for themselves and their families (Chen, 2007; Krystallis and Chryssohoidis, 2005; Davies, Titterington and Cochrane 1995; Dreezens *et al*, 2005; Makatouni, 2002; Stobbelaar *et al*, 2007). Organic consumers believe that organic food is safer than conventional food (Krystallis and Chryssohoidis, 2005). Consumers also value environmental conservation and wellbeing. As Makatouni (2002) pointed out, consumers valued environmental health because it is associated with their wellbeing. Consumers believed that healthy environments produce healthy food and healthy people: “You are what you eat” (Makatouni, 2002, p350). Studies carried out in United Kingdom and elsewhere showed that consumers felt that organic foods were healthier, more nutritious and taste better (Brennan, Galagher and McEachern, 2003; Johansson *et al*, 1999; Poelman *et al*, 2008). Research has shown that organic food was generally more nutritious than conventionally produced foods (Magkos, Arvaniti and Zampelas 2003; Worthington, 2001).

Although consumers of organic produce are often supporters of environmentally friendly production, they are also typically quality and food safety conscious (Kirsten and Sartorius, 2002). A common misconception is that organic consumers will accept low quality produce in return for perceived benefits of organic produce (Saunders, 2004). To the contrary, organic produce presented for sale should be of high quality. Placing poor quality produce on sale tends to have an adverse impact on consumer acceptability and damage the prospects for future sales, however good the actual or apparent cooking quality (Saunders, 2004). Organic producers therefore need to ensure that their produce meets the quality standards necessary to convince buyers to pay premium prices for products.

Appearance quality and freshness constitute primary factors affecting consumer purchase intentions (Péneau *et al*, 2006). However, repeat purchases are mainly a result of experienced quality (Grunert, 2002 and Tsiotsou, 2006). Post harvest

handling and storage of perishable products like potatoes needs to ensure that the produce maintains appearance, sensory and keeping qualities to penetrate and secure access to niche markets. Supermarkets that buy from small scale organic farmers tend to emphasise the marketing of horticultural products of high quality as a way of competing with rival markets (Berdegué *et al*, 2005). A clear understanding of consumer quality expectations is essential for the farmers to ensure that the produce they supply convinces competitive supermarkets to keep them as suppliers of organic produce.

2.3 Importance of potatoes as a food and cash crop

Potatoes (*Solanum tuberosum* L.) are classified as a horticultural crop and are one of the most important cash and food crops in the world (International Potato Centre, 2002). The potato is the world's fourth most important food crop after wheat, rice, and maize in terms of production volumes and consumption (Eltawil, Samuel and Singhal, 2006; Sonnewald, 2001). About 35% of world production is in developing countries where potato is an important part of the diet (International Potato Centre, 2002).

For small scale farmers, potato is an important food crop that is often available when adverse climatic conditions threaten basic food supply and during the lean seasons (Tanganik *et al*, 1999). Potatoes are rich in carbohydrates, have high quality protein (albeit low per unit value) and high levels of Vitamin C (Fialdo, Santos and Salama, 2000; Şengül, Keleş and Keleş, 2005; Worthington, 2001). In addition to food, potatoes are a source of income to small scale farmers (Scott, 2002).

South Africa produces 1.6 million tons of potatoes annually (Potatoes South Africa, 2000) and is one of the major potato producing countries in Africa (International potato Centre, 2002). Among field crops, potato ranks fifth in value after maize, wheat, hay crops and sugarcane (Sanewe and Young, 2000). In KwaZulu-Natal, potatoes are positioned as the most valuable vegetable and the fourth most important crop after maize, sugarcane and hay in terms of value (Sanewe and Young, 2000).

Potatoes are marketed as seed, processing and table potatoes. In South Africa, table potatoes are the most important economically providing 63.5% of the total crop market share (Theron, 2003). Table potatoes are an important cash crop in organic niche market (Willer and Yussefi, 2007; Yussefi, 2006). The premium prices paid for products in organic markets present an opportunity for small scale farmers to increase income. Due to the growth in organic niche market in South Africa, supermarkets are demanding greater quantities of organic baby potatoes to satisfy consumer demand (Ferreira, 2004 and Makhanya, 2005). Farmers need to make sure that their produce meets consumer and supermarket quality expectations exploit opportunities in niche market and to gain premium prices.

2.4 What constitutes potato quality?

Access to markets is increasingly seen as an essential element in providing a route out of poverty for small scale producers in rural areas (Page and Slater, 2003). A step towards continued access to markets is a demonstration of consistent production of quality and safe produce (Berdegué *et al*, 2005). Potatoes are a semi perishable product that requires appropriate and efficient post harvest technology to minimise losses and maintain quality ((Eltawil, Samuel and Singhal, 2006 Suttle, 2004a).

French (1981) explains that potato quality consists of three categories: sensory, consumer (appearance) and storage qualities. Carbohydrate content and the *glycoalkaloid* content of potatoes affect the sensory quality of potatoes. Greening, size, sprouting, diseases and pest damage affect potato appearance quality. The keeping quality of potatoes in storage is in part pre-determined by cultivar; production practices and maturity of tubers at the time of harvesting (Kehoe, 2000; Rastovski, 1987; Storey and Davies, 1992; Wilson *et al*, 1995). In the following subsections, factors that affect the sensory, appearance and keeping quality of potatoes are discussed to shed more light on how the qualities can be preserved.

2.4.1 Potatoes sensory characteristics

The sensory characteristics of potatoes are affected mainly by the carbohydrate composition and the glycoalkaloid content of the potatoes (Storey and Davies, 1992).

Both characteristics are affected by cultivar, production and storage conditions (Storey and Davies, 1992). The following two subsections discuss the carbohydrate composition and the glycoalkaloid content to show how they affect the sensory quality of potatoes.

2.4.1.1 Carbohydrate content of potatoes

Carbohydrate content of potato tubers is central to the cooking and sensory quality of potatoes (Kaaber *et al*, 2001; French, 1981; Warren and Woodman, 1974). Starch is the main carbohydrate of the potato tuber (Burton, 1989) and accounts for 60 to 80 per cent of the dry matter content of potatoes (van Es and Hartmans, 1987). Other carbohydrates in potatoes include sugars and cellulose (Burton, 1989).

As a living organism, a potato tuber respire (Diop and Carverley, 1998). During storage, starch is converted to sugars for respiration. When the rate of conversion of starch to sugars exceeds the rate at which they are utilised, sweetening occurs (Hertog *et al*, 1997). This is mainly influenced by storage temperature and the age of the tuber (Storey and Davies, 1992; Burton, 1989). Cold storage below 6°C results in cold induced sweetening while in long-term storage, ageing causes senescent sweetening (Storey and Davies, 1992; Burton, 1989a). Sugar levels in potatoes also increase as a result of mobilisation of carbohydrates to support sprouting (Burton, 1992). The accumulation of reducing sugars alters flavour, texture and considerably affects quality and consumer acceptance (Galicia-Cabrera *et al*, 2002). High reducing sugar levels result in undesirable brown colouring in fried potato products (Mackay, Brown and Torrance, 1990). In boiled and baked potatoes, high levels of sugars result in a soggy texture (Burton, 1989a).

The effect of delayed or sequential harvesting (*in situ* storage) on potato carbohydrate content has been studied. In a study by Dogras, Siomos and Psomakelis (1991), no significant changes were observed in the carbohydrate content of tubers left *in situ* for three months with diurnal temperature fluctuations between 4.8-15.1 °C. Noda *et al* (2004) found that delaying harvesting by four weeks post maturity resulted in negligible decrease (1%) in starch content of potatoes of various cultivars. However,

there seems to be no published data on the impact of changes in the carbohydrate composition of sequentially harvested organic potatoes on their sensory properties.

2.4.1.2 *Glycoalkaloid content of potatoes*

Glycoalkaloids are naturally occurring nitrogenous toxic compounds in the *Solanaceae* family (Bacigalupo, Longhi and Meroni, 2004; Percival, Dixon and Sword, 1996). The main glycoalkaloids in potatoes are α -solanine and α -choconine (Mondy and Gosselin, 1988; Savage, Searle and Hellenäs, 2000). These compounds are important in the natural defence of the plants against insects, fungi and viruses (Hollister *et al*, 2001; Storey and Davies, 1992; Wierenga and Hollingworth, 1992). Lower concentrations of *glycoalkaloids* contribute to desirable potato flavour (Abell and Sporns, 1996). However, Storey and Davies (1992) and Griffiths, Bain and Dale (1997) and Şengül, Keleş and Keleş (2004), citing a number of authors, reported that glycoalkaloid content of more than 10 mg/100g fresh weight results in a bitter taste in potatoes. Potatoes with glycoalkaloid content of above 20 mg/100g fresh weight have been reported to be toxic for humans (Korpan *et al*, 2004).

Abreu *et al* (2007) compared the glycoalkaloid content of two potato cultivars of potatoes grown under organic and conventional production systems. The results showed conflicting results. In the case of one cultivar there were no significant differences while the other cultivar recorded higher glycoalkaloid content in organically grown potatoes. The researchers' conclusion from the study concurred with Korpan *et al* (2004) that glycoalkaloid content of potatoes may be largely dependent on potato cultivar.

Increase in total glycoalkaloid content of potatoes in storage has been attributed to exposure to light and storage temperature. In a study of three potato cultivars reported that exposure to daylight increased the rate of glycoalkaloid synthesis in each cultivar (Perceival, Dixon and Sword, 1996). However, Machado, Toledo and Garcia (2007) reported an increase in glycoalkaloid content of potatoes stored in darkness under refrigerated conditions (7-8 °C). Accumulation of glycoalkaloids in potatoes stored at low temperature was also reported by Griffiths, Bain and Dale (1998). However, the intensity of the effect of temperature on glycoalkaloid synthesis was cultivar dependent (Griffiths, Bain and Dale, 1998).

Glycoalkaloids are not destroyed during potato processing or cooking (Percival, 1999 and Percival, Dixon and Sword, 1996). Glycoalkaloids are concentrated in the 1.5 mm layer of the cortical and storage tissue under the potato skin and peeling removes 60-96 % of the glycoalkaloid content (Maga, 1994; Wszelaki *et al*, 2005). Mondy and Gosselin (1988) studied the effects of boiling and steaming on glycoalkaloid content of peeled and unpeeled potatoes sized 50-80g. Results showed that glycoalkaloids migrated into the inner portions of the potatoes or leached into the water especially in boiled potatoes. Leaching reduced the glycoalkaloid content of the potatoes and the migration into the flesh of the potatoes resulted in bitter unpeeled potatoes.

2.4.1.3 Sensory evaluation of potatoes

Various cooking methods can be used in preparing potatoes for sensory evaluation. The selection of method depends on the intended product for the potatoes being tested. For table potatoes, steaming is recommended because it results in minimal leaching of chemical components from potatoes (Savage, Searle and Hellenäs, 2000).

A number of sensory valuation methodologies are available for use including descriptive analysis, texture evaluation, colour and appearance, acceptance and preference testing (Lawless and Heymann, 1998). The choice of methodology depends on the purpose of evaluation. Consumer acceptance and preference testing covers a number of attributes that consumers use to select one product over another (Savage, Searle and Hellenäs, 2000). In the measurement of acceptance, consumers rate their liking of a product on a hedonic scale (de Kock and Minnaar, 1998). In preference measurement, the consumer panellist expresses a choice or preference for one product over another or others (Lawless and Heymann 1998).

Preference ranking is simple and can be conducted with minimal effort (Tepper Shaffer and Shearer, 1994). This is a useful tool especially where time is limited. Lawless and Heymann (1998) state that where ties (assigning the same preference rank number to two or more products) are allowed and where no ties are allowed in the ranking of products, Friedman's test and Baskers tables can be used to analyse the data respectively. Basker's table analysis is user-friendly. In this test, if there are seven products to evaluate and six panellists, the rank assigned by each panellist for a

given product are added as shown in Table 2.1. The products are then arranged in ascending order according to the rank sums (Table 2.2). The significant difference between products is then checked under seven products and six panellists in Basker's tables. In this case the critical difference value between any two products is 22 (Lawless and Heymann, 1998). Product D (a), in Table 2.2, is more preferred than product G (b). No significant differences are observed among the other products in Table 2.2. Preference ranking using Basker's table analysis is efficient and user friendly when investigating the significance of differences in consumer preferences products.

Table 2.1. An example of ranking results of seven products by six panellists and rank sums per product (Lawless and Heymann, 1998, p446)

Panellist	Product	1	2	3	4	5	6	Rank sum
	A	3	2	4	2	4	3	18
	B	7	3	2	3	6	7	28
	C	2	5	7	1	3	2	20
	D	1	1	1	5	1	1	10
	E	5	4	3	7	2	5	26
	F	4	7	6	4	7	4	32
	G	6	6	5	6	5	6	34
	Totals	28	28	28	28	28	28	168

Table 2.2. Testing the significance of differences in preference rank sums using Basker's critical difference value (22) for seven products and six panellists (Lawless and Heymann, 1998, p446)

Product	D	A	C	E	B	F	G
Rank Total	10	18	20	26	28	32	34
Significance group	a	ab	ab	ab	ab	ab	b

2.4.2 Potato Greening

Exposure of potato tubers to light results in greening due to chlorophyll accumulation (Percival, 1999). Before harvesting, tubers may be exposed to light due to insufficient soil cover (Lewis and Rowberry 1973). Potato greening is undesirable due to health and marketability reasons (Grunenfelder, Hiller, and Knowles, 2006). Greening is generally accompanied by glycoalkaloid synthesis (Machado, Toledo and Garcia, 2007). Consequently, greening potatoes are usually rejected by both consumers and processors, resulting in economic losses (Grunenfelder, Hiller, and Knowles, 2006; Storey and Davies, 1992). In South Africa, potatoes are classified unacceptable for class one if the greening covers more than 10% of the tuber surface (National Department of Agriculture, 2005). However, supermarkets selling organic baby potatoes expect no greening in potatoes presented for sale (Ferreira, 2004).

Short, repeated exposure to day light has been shown to accelerate greening more than single extended exposures (Akeley, Houghland and Schark, 1962; Brown and Riley, 1976). Therefore, frequent opening of dark potato storage facilities in daylight is not advisable. Low temperature storage has also been recommended because research has shown that potatoes stored at 20°C have more extensive greening than potatoes stored at 5°C (Storey and Davies, 1992). Cultivars need to be studied independently to understand the effect of storage on losses due to greening. Akeley, Houghland and Schark (1962) reported that that greening response in potato tubers is cultivar dependent.

2.4.3 Potato sprouting and dormancy

Botanically, a potato tuber is a highly compressed stem, and the eyes correspond to apical and lateral auxiliary buds (Suttle, 2004a). At maturity, potatoes are in a state of dormancy during which bud growth will not occur even under otherwise favourable conditions due to endogenous physiological and biochemical factors (Suttle, 2004b; Burton 1989b). Burton (1989b) refers to this type of dormancy as endodormancy and states that it begins at the time of tuber initiation and can be affected by pre- and post-harvest environmental factors.

The onset of sprouting in potatoes adversely affects chemical characteristics and appearance of potatoes resulting in financial losses (Destefano Beltran *et al*, 2006; Suttle, 2004b). In storage, sprouting increases weight loss through desiccation (Frazier, Olsen and Kleinkopf, 2004). A long period of dormancy is desirable for table potatoes to increase the storage or shelf life (Alexopoulo *et al*, 2007). Potatoes with visible sprouts are unacceptable to consumers (Frazer, Olsen and Kleinkopf, 2004).

2.4.3.1 Factors affecting potato dormancy

Researchers have demonstrated that endogenous sprout inhibiting and sprout promoting hormones play a vital role in potato tuber sprouting (Coleman, Donnely and Coleman, 2001; Cutter, 1992; Suttle 1998). Phytohormones, abscisic acid, ethylene, gibberellins and cytokinins have been posited as principal regulators of tuber dormancy initiation and maintenance (Coleman, Donnely and Coleman, 2001, Destefano Beltran *et al*, 2006; Suttle, 2000; Suttle 1998). However, research has consistently shown that while gibberellins promotes growth of sprouts after dormancy break and decreasing levels of abscisic acid with dormancy break, they do not play a role in dormancy control *per se* (Sonnewald, 2001; Suttle 1995; Suttle 2004a). Ethylene reportedly controls sprouting (Jeong, Prange and Daniels-Lake, 2002; Suttle, 1998). Whatever the chemicals involved, the endo-dormancy period depends on the pace at which the biochemical balances change to reach a level that promotes growth (Burton, 1989).

The pace of this change is influenced by the initial state of balance, as determined by the cultivar, production conditions and the environmental conditions post maturity *in situ* and post harvest in storage (Burton, 1989). Photoperiod during growth and temperature in storage regulate sprouting behaviour (Sonnewald, 2001). The effect of photoperiod in the production period may explain the observation by Suttle (2004b), that tuber dormancy varies from season to season. Photoperiod affects photosynthesis, which in turn affects the carbohydrate content of tubers and consequently the readily available assimilates to support sprouting (Burton, 1989).

Suttle 1995 showed that irrespective of the abscisic acid levels, sprouting was delayed in tubers stored at 3°C compared to those stored at 20°C. In a study of three potato

cultivars left in *situ* for three months (minimum temperature of 4°C and maximum average temperature of 14.7°C), sprouting did not occur (Dogras, Siomos and Psomakelis, 1991). However, progression of potato dormancy after harvesting was not investigated.

Changes in environmental conditions surrounding the tuber because of harvesting seem to affect the dormancy of harvested tubers. Bruinsma and Swart (1970) observed that dormancy in potatoes seemed to intensify after harvesting, probably due to shifts in metabolic pathways or periderm adapting to the air environment. It may be posited therefore that sequentially harvested potatoes and potatoes harvested upon maturity from the same crop may have different endodormancy durations. Previous research suggests that the later harvesting takes place, the shorter the expected dormancy period (Bruinsma and Swart 1970; Lommen, 1993). However, Bruinsma and Swart (1970) point out that the course of dormancy is affected by storage conditions. For instance Kleinkopf, Oberg and Olsen (2003) reported that potatoes stored under fluctuating temperature and humidity conditions tend to age faster, physiologically, and consequently sprout faster than those stored under non fluctuating conditions.

2.4.3.2 *Measuring potato dormancy*

As a matter of convenience, researchers take the time of tuber harvesting as the point of dormancy commencement (van Es and Hartmans, 1987, Cutter, 1992; Lommen, 1993). However, being decided by the farmer, the time of harvesting does not have any relationship to the physiological age of the tuber *per se*. This is because the physiological age is about the length of existence of tuber from formation. Burton (1982) suggested that the most logical point from which to measure dormancy physiologically and biochemically is at tuber initiation. However, Burton's method has not been widely accepted (Cho, Iritani and Martin, 1983). From the keeping quality point of view, dormancy is still measured from the time of harvesting to the time of sprouting (Cho, Iritani and Martin, 1983; Cutter, 1992; Lommen, 1993; Suttle, 1998).

Researchers have used storage temperatures ranging from 18°C to 20°C and relative humidity of between 80% and 90% to determine post harvest dormancy of potatoes (Bruinsma and Swart, 1970; Lommen, 1993; Ruest, 1986; Suttle 1998). Experiments are carried out in dark chambers. Bruinsma and Swart (1970) placed the tubers with the apical eye facing upwards on a shallow layer of moist sand, but Lommen (1993) used a shallow layer of air-dried sand. Visual assessment of sprouting was carried out weekly. The dormant period of a batch of potatoes was regarded as a period from harvest until 50 % of the potatoes bore a sprout of ≥ 2 mm (Lommen, 1993; Suttle 1998). Moisture constitutes a favourable condition for potato sprouting (Sonnewald, 2001) and therefore, use of sterilised wet sand may be desirable. Sterilisation of the sand is useful to prevent external infection from the sand in the humid, dark chamber.

2.4.3.3 Methods for extending potato tuber dormancy

Conventionally, sprouting is controlled through the use of synthetic sprout inhibitors such as isopropyl N-(3-chlorophenyl) carbamate (chlorpropham) and maleic hydrazide (Destefano Beltran *et al*, 2006; Kneinkopf, Oberg and Olsen, 2003; Sonnewald, 2001). Environmental concerns have resulted in a search for eco-friendly organic alternatives to these chemicals (Kerstholt, Ree and Moll 1997). Research has demonstrated that natural products like s-carvone extracted from caraway seed (*Carum carvi*) and spearmint (*Menta spicata*) and peppermint (*Menta piperita*) oils are effective in preventing sprouting in potatoes (Kneinkopf, Oberg and Olsen, 2003). However, the cost of these compounds, given necessary repeated application and the fact that they are not readily available in third world countries, makes them a far fetched option for small scale organic farmers.

Low temperature storage is also used to prolong dormancy (Sonnewald, 2001). However, cold storage reduces the dormant period for the tubers when they are returned to normal temperature (Lommen, 1993; van Ittersum and Scholte, 1992). Consequently, the keeping quality of cold stored potatoes may be compromised after sale. Secondly, as indicated earlier in this chapter, cold storage results in cold induced sweetening and accelerated glycoalkaloid accumulation, negatively affecting the sensory characteristics of the potatoes (Griffiths, Baine and Dale, 1998). The method

may also not be affordable for small scale farmers since cold rooms require substantial initial capital.

2.4.4 Potato tuber diseases and pests

Potato disease and pest control is vital to ensuring good yields, maintaining produce quality and maximising marketable yield (Larkin, 2008). The potato is subject to more than a hundred diseases caused by fungi, bacteria and viruses (Hide and Lapwood, 1992). Fortunately, few potato diseases are a serious problem in any given production area (Hide and Lapwood, 1992). However, post harvest potato diseases are responsible for significant economic losses (Mills, Platt and Hurta, 2004).

In South Africa, potato scab caused by *Streptomyces scabies*, fusarium dry rot caused by *Fusarium solani* and soft rot caused by *Erwinia carotovora* are economically important potato diseases affecting the quality of table potatoes (Gouws and Mienie, 1997; Theron and Holz, 1990; Urquhart, 1997). Nematodes (*Meloidogyne spp.*) and millipedes are among the main potato tuber pests in KwaZulu-Natal (Steyn, 1997; Visser, 1997; Visser, 2005). Identification of pests and diseases affecting potato produce of organic farmers in a given area is a pre-requisite to identifying existing and developing new organic friendly loss mitigation measures.

2.5 Summary

Organic farming presents an opportunity for small scale farmers to increase income and production through participation in lucrative organic niche markets. This is particularly the case in South Africa where many subsistence farmers traditionally practice organic farming and already have the fundamental skills and knowledge in organic production of crops. Potatoes are one of the most important horticultural food and cash crop in the organic niche market grown by small scale farmers in South Africa.

Potatoes are a semi-perishable product. Quality loss results in reduced quantity of marketable produce and may lead to loss of markets. An understanding of consumer quality expectations in niche markets would help farmers to present acceptable produce to the market. Research aimed at identifying the challenges small scale

farmers face in preserving desirable quality characteristics in potatoes is necessary. Such research is required to identify post-maturity and post-harvest produce handling techniques that maintain desirable produce appearance, sensory and keeping quality characteristics.

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CHAPTER 3: DESCRIPTION OF THE STUDY AREA AND EFO

3.1 Location of the Ezemvelo Farmers Organisation

The Ezemvelo Farmers Organisation (EFO) was founded and operates in Embo in Umbumbulu District, KwaZulu-Natal in South Africa (Gadzikwa, Lyne and Hendriks 2006). Embo is situated south-west of Durban (Figure 1). and has an estimated population of 160 755 people dispersed over a wide geographic area (South African Explorer, 2001).



Figure 3.1: Map of Durban and the surrounding areas showing the location of Embo, the study site (KwaZulu-Natal Tourism Authority, 2002).

The area is rural and is part of the former KwaZulu homeland characterised by traditional forms of land tenure and subsistence agriculture (Ortmann and Machete

2003). These previous homelands are typically characterised by widespread poverty (Agergaard and Birch-Thomsen, 2006)

Farming is a dominant livelihood strategy in the area (Agergaard and Birch-Thomsen, 2006). However, Msaki *et al* (2005) reported that the main sources of income were remittances and grants. Bekker (2003) confirms that grants are an important source of revenue for rural South African communities. Previous and current urban employment of family members provides essential capital (through pensions, salaries and remittances) for the advancement of agriculture in Embo (Agergaard and Birch-Thomsen, 2006).

Most small scale farmers in the area have knowledge of and practice organic farming (Modi, 2003). The farmers use their knowledge, access to land, in some cases access to capital (from grants and off-farm employment) and favourable agricultural productivity of their area to increase income from farming (Agergaard and Birch-Thomsen, 2006). Sugarcane farming and organic farming provided an opportunity for small scale farmers to convert to commercial farming (Agergaard and Birch-Thomsen, 2006). Through organic niche markets, farmers had an opportunity to scale up and perfect agricultural production to generate income. The formation of the EFO helped farmers produce quantities demanded by markets through collective production and marketing of produce.

3.2 Description of the EFO

The EFO is a group of traditional organic farmers (Modi, 2003). EFO was formally founded in February 2001 when a group of 40 subsistence farmers from Ogagwini with the help of Prof Albert Modi, a seed specialist from the then University of Natal (Gadzikwa, Lyne and Hendriks, 2006; Agergaard and Birch-Thomsen, 2006). The farmers had a common interest to improve production, quality management and marketing of traditional crops like *amadumbe (taro)*, sweet potatoes and baby potatoes (Agergaard and Birch-Thomsen, 2006). Encouraged by the group's determination to succeed, Prof Albert Modi and Dr James Hartzell of Assegai Organics helped the farmers attain organic certification in 2002. AFRISCO, an

accredited South African local organic certifying body, assisted the farmers by offering them certification *pro bono*. The group was the first group of small scale farmers to gain certification in South Africa (Ndokweni, 2002).

The 'certified organic' status enabled the farmers to market their produce to Pick 'n Pay retail chain and later to Woolworths. The success of the group encouraged other players to come on board. In 2002/03, the EFO farmers received support in the form of training and farm fencing (to protect their crops from livestock) from a partnership between KwaZulu-Natal Department of Economic Development and Tourism, provincial Department of Agriculture and Environmental Affairs, University of KwaZulu-Natal (UKZN) and Woolworths (Pty) Ltd (Gadzikwa, Lyne and Hendriks 2006). At the time of this study, Woolworths was working to help the farmers diversify production through production of indigenous chickens.

The EFO had an open membership policy where farmers were free to join as long as they met qualifying requirements stipulated in the group's constitution. An EFO Certification Committee, made up of elected members from the general membership processed applications from prospective members. The committee also ensured compliance with organic rules. The Certification Committee made recommendations on accepting or rejecting applications to the EFO Management Committee. The Management Committee comprised of chairperson and vice chairperson, secretary and deputy secretary, treasurer, and three elected members from. This committee made final decisions regarding acceptance or rejection of applications for membership, based on the recommendations from the Certification Committee. The Management Committee acted as a Board of Directors responsible for overall strategic guidance and exercising control over the organisation's assets and resources.

The open door policy of the EFO allowed the organisation to expand from the initial 54 farmers to 161 members from 127 households at the time of this study. Of the 161 members, 48 were fully certified organic farmers who had met certification requirements of AFRISCO and were endorsed as certified by AFRISCO. The other 113 were partially certified. The partially certified farmers were provisionally accepted by the Certification Committee having fulfilled all the EFO requirements and presented to AFRISCO for certification approval.

Under the group certification arrangement, the EFO farmers owned and managed their individual plots. The farmers sourced their own inputs for production, prepared their plots for planting and decided on which crops and how much to plant in each season. Crop maintenance, harvesting, grading and storage were also individual farmer's responsibility. However, one farmer's violation of the guidelines for organic production could cost the entire organisation its certified status. To maintain their certified organic status, the EFO trained eight internal inspectors who monitored each member's compliance with the requirements and restrictions of organic production. Transgressions were reported to EFO Certification Committee who would consider the matter, hold disciplinary hearings and make recommendations to the Management Committee for action. The inspectors were paid by the organisation to play an internal monitoring role at a much reduced rate compared to inspection charges of certification agencies.

Farm size for the small scale farmers in the area was varied. The mean farm sizes were 0.48, 0.77 and 0.75 hectares for non-EFO members, partially certified members and fully certified members respectively (Hendriks and Msaki, 2006). The farmers who engaged in organic farming generally had an incentive to expand their farm sizes to increase their production and consequently income. Farm income contributed 2.36, 5.05% and 7.53% to household income of EFO non-member households, households of partially certified and certified members respectively (Hendriks and Msaki, 2006). Although farmers sold some of the produce to local buyers they principally supplied their produce to Woolworths via a certified organic pack house called Assegai Organics.

3.3 Marketing of EFO organic produce

At the beginning of each season, the EFO farmers and the pack house negotiated prices for the season. Farmers did not benefit from market related price fluctuation. The farmers did not have their own reliable means to transport produce to the market (Darrock and Mushayanyama, 2006). They depended on transport previously provided by the Department of Agriculture and Environmental Affairs and Assegai

Organics pack house (Ndokweni, 2002). This limited access to alternative markets, except where informal market buyers bought the produce directly from the farmers.

The pack house communicated the amount and type of produce which the EFO had to supply. To ensure that all farmers had a chance to sell some of their produce on each collection time, farmers were allocated an equal supply quota. If some farmers failed to supply their quota, others would fill the gap. Nevertheless, this limited the amount of produce a farmer could supply at once. Farmers who were unable to sell all their produce at crop maturity needed effective storage strategies to minimise post maturity and post harvest losses. The pack house graded the produce before supplying Woolworths. Produce of unacceptable quality was returned to the farmers, constituting loss.

Organic farming had potential to contribute significantly to the sustainability of farming as a livelihood for EFO farmers (Agergaard and Birch-Thomsen, 2006). For sustainability, farming needs to be profitable through production of high quality produce that meets consumer expectations (Page and Slater, 2003). Page and Slater (2003) suggest that small scale farmers could benefit from research that enables them to understand markets, consumer expectations and how to satisfy quality expectations. This study contributes to the farmers' understanding of the organic potato market, consumer quality expectations and the role of traditional storage practices in preserving the quality of produce to improve farm incomes.

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CHAPTER 4: EFFECT OF TRADITIONAL STORAGE PRACTICES OF SMALL SCALE ORGANIC FARMERS ON POTATO QUALITY¹

4.1 Introduction

Organic agriculture encompasses farming methods that exclude application of synthetic fertilizers and pesticides (Rundgren, 2004). Some advantages of organic farming are: increased income through access to premium export markets and supermarkets; reduced inputs and costs of production and recognition of the value of integrating traditional and indigenous knowledge in crop production (Rundgren, 2004). Despite opportunities to increase production and income offered by organic farming, small scale organic farmers are faced with the challenge of maintaining good quality produce (Reardon and Berdegué, 2002; Dries, Reardon and Swinnen, 2004) and minimising post harvest losses of perishable horticultural products such as potatoes. Unlike other major food crops, potatoes are stored in a fully hydrated, highly perishable form (Suttle, 2004; Sonnewald, 2001).

Changes in starch and sugar content are important in determining the sensory quality of stored potatoes (Burton, van Es and Hartmans, 1992). Storage quality alterations in potatoes are partly caused by physiological changes and environmental factors (Suttle, 2004; Shewfelt 1999; van Oirschota *et al*, 2003; Hertog, Putz and Tijskens, 1997; van Es and Hartmans, 1987; Dahiya *et al*, 1997; Burton, 1989). During storage, starch is converted into sugars due to senescence, respiration and cold temperatures, especially below 10°C (Hertog, Putz and Tijskens, 1997; van Es and Hartmans, 1987a; Burton, 1989; Sparenberg, 1987; Cheong and Govinden, 1998). When the net production of sugars exceeds use, sugars accumulate in the potato (Hertog, Putz and Tijskens, 1997). Total sugar content above 12.5 gkg⁻¹ causes a sweet taste and soggy texture in potatoes (van Es and Hartmans, 1987b). Appropriate storage of potatoes prior to marketing is therefore central to quality maintenance and consumer satisfaction (Shewfelt, 1999; van Oirschota *et al*, 2003).

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Crop storage is especially difficult for small scale farmers due to lack of storage facilities and technologies (Thamaga-Chitja *et al*, 2004). Over time, small scale farmers have developed ways to mitigate against post harvest potato losses. For example, small scale organic farmers of the Ezemvelo Farmers Organisation (EFO) in South Africa leave potatoes *in situ*, harvesting the crop sequentially as and when needed. Once harvested, potatoes are stored on mud floors of traditionally thatched houses.

Previous studies on the effect of leaving potatoes *in situ* for varied times have focussed on conventionally produced potatoes and concentrated on produce loss, changes in dry matter content and reducing sugar content (de los Santos, Bautista and Potts, 1986; Dogras, Siomos and Psomakelis, 1991). Research on sensory characteristics of organically produced potatoes has mainly focussed on comparison of conventional and organic potatoes (Wszelaki *et al*, 2005). It is well known that cultivar, fertilizer treatment, geographic location and storage conditions affect the carbohydrate content of potatoes (Dogras, Siomos and Psomakelis, 1991; Burton, 1989, van Es A and Hartmans, 1987). However, no studies have explored the quality changes in organically produced potatoes tubers left *in situ* compared with tubers harvested and stored using traditional storage (i.e. storage in traditionally thatched houses) as practiced by small scale organic farmers in South Africa.

The main objective of this study was to investigate the effect of traditional farmer's store, *in situ* and controlled storage on the carbohydrate content and sensory quality of potatoes organically grown in Embo by EFO farmers. Specifically, this chapter aims compare the effect of traditional, *in situ* and controlled (7°C and 90% relative humidity) storage, on total sugar and starch content of organically produced potatoes of a landrace cultivar and to compare the effect of traditional, *in situ and* controlled (7°C and 90% relative humidity) storage on sensory preference of the potatoes.

4.2 Research methodology

Potatoes of a traditional cultivar were produced organically at Embo. Three small scale certified organic farmers of the EFO produced the potatoes in three seasons:-

summer of 2004 and autumn and winter of 2005 under dry land conditions. Harvesting commenced after crop maturity, according to farmers' practice, approximately 14 weeks from planting. The field was divided into 12 plots of the same area. Potatoes were harvested manually from three randomly selected plots and potatoes in the remaining plots were left *in situ* and were harvested sequentially at two week intervals. After harvesting, the potatoes were manually sorted to remove all damaged, rotting, sprouted and greening potatoes. Baby potatoes measuring 30-45 mm in length and weighing 30-50g were used in the experiments. Potatoes of this size category fetch premium selling prices for these small scale farmers.

The potatoes were packaged in nylon net bags and randomly assigned for traditional and controlled storage. Farmers reported rapid sprouting of the potatoes. A temperature of 7°C was therefore used in the controlled storage to simultaneously mitigate rapid sprouting and avoid cold-induced sweetening (Wszelaki *et al*, 2005). Onset Hobo[®] H8 data loggers (Onset Computer Corporation Pocasset, Massachusetts, United States of America) were used to monitor temperatures at 5, 10, 15, and 20 cm depths in the soil and the ambient temperature in the farmer's traditional storage house (Figure 4.1 presents weekly average temperatures). Although the farmer's storage house was dark, the potatoes were periodically exposed to indirect sunlight when the house was opened.

4.2.1 Carbohydrate content analysis

Starch and sugar content were determined every two weeks during storage. Ten potatoes from each treatment were sampled in three replicates. The tubers were chopped into ≤ 2 cm cubes, frozen in liquid nitrogen and freeze-dried at -52°C in a vacuum of 30 millitorr for 23 hours using a Virtis[®] Bench Top 6K Freeze dryer (SP Industries, New York, United States of America).

Dried samples were finely ground using a pestle and mortar and 1.5 g of each sample was placed in a 25 ml volumetric flask. Sugars were extracted in 500 gkg⁻¹ ethanol and 500 gkg⁻¹ water for 30 min in an ultrasonic water bath at 60°C, cooled to room temperature and made up to volume with 500 gkg⁻¹ ethanol and 500 gkg⁻¹ water. Analysis for sugars, glucose, fructose, maltose, sucrose and total sugar content, were

performed using high performance liquid chromatography (HPLC) following the AOAC Official Method 982.14 (Association of Official Analytical Chemists, 2003). Samples for starch content analysis were prepared by enzymatic digestion based on the AOAC method 991.43 as described by Cho and Prosky (1999), diluted to 200 ml with 500 gkg⁻¹ ethanol and analysed for sugars using HPLC.

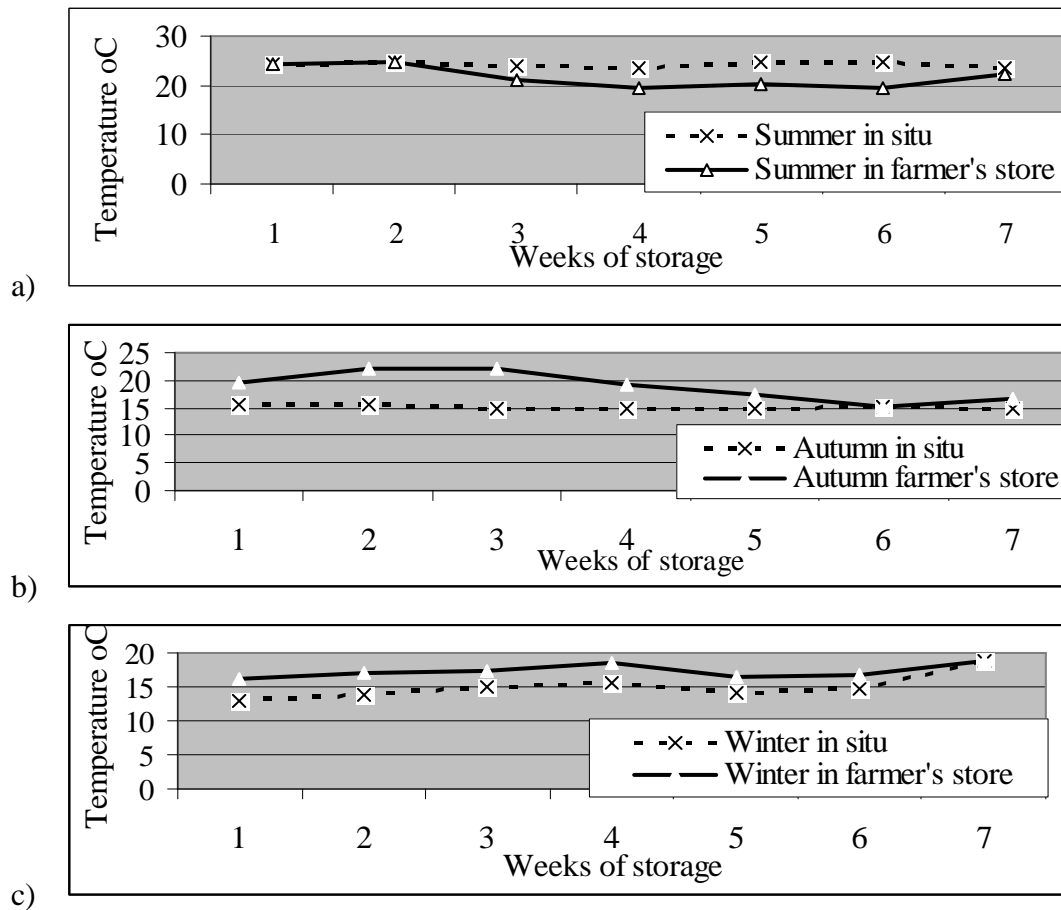


Figure 4.1: Soil and ambient temperature patterns where potatoes were left in situ and in the farmer's storage respectively for the seasons a) summer, b) autumn and c) in winter.

The HPLC system used was the Angilent 1100 series (Waldbronn, Germany) that had a 30 µl auto injector connected to an Angilent Zorbax (USCY001510) column (Waldbronn, Germany). The mobile phase was 830 gkg⁻¹ acetonitrile and 170 gkg⁻¹ water at a flow rate of 33.33 µl s⁻¹ monitored using an Angilent refractive index detector (Waldbronn, Germany). Results were quantified using Angilent Chemstation software for instrument control and data processing (Waldronn, Germany).

4.2.2 Sensory evaluation

Sensory evaluation was performed at 2, 4 and 6 weeks of storage. Forty potatoes from each treatment were washed to remove dirt and steamed unpeeled, for about 45 min until a kitchen fork easily penetrated them (Savage, Searl and Hellenas, 2000). While warm, the tubers were cut in half along the bud stem axis. Each sample was presented to 60 volunteer panellists on a white plate. The sample was labelled with a unique random 3-digit number obtained from a table of random numbers (Babbie and Mouton, 2001). The order of sample presentation to each panellist was determined by random permutations obtained from a random permutations generator (Department of Statistics, 2005). Before commencing sample tasting, and before tasting the next sample, the panellists rinsed their palates with water. Plastic forks were used the potatoes and panellists were instructed to avoid eating the potato skin. Preference ranking based on panellists' overall perception of the sample was used. Samples were ranked from the most preferred (1) to the least preferred (3) on a questionnaire (Appendix 1). Panellists were instructed that ties in preference ranking scores were not acceptable. In addition, the panellists were asked to comment on how they decided on their ranking of the samples.

Participation in the sensory evaluation panel was voluntary. Advertisements for panellists were posted at the Pietermaritzburg Campus of the University of KwaZulu-Natal. Staff and students signed up. The participants were trained in two sessions on the sensory evaluation procedure. Participants signed a consent form for voluntary participation (Appendix 2). Ethical clearance for use of human subjects (panellists) was granted by the University of KwaZulu-Natal Research Office (Appendix 3).

4.3 Data analysis

SPSS release 13.0 for Windows (SPSS Inc., Chicago, Illinois, United States of America) was used to analyse the carbohydrate content data. Analysis of variance (ANOVA) was used to compare the means of sugar and starch content, in particular, the least significant difference (LSD) method was used for pair wise comparisons of the means. Pearson's correlation analysis was performed to establish the relationship between carbohydrate content and the total preference ranking score. Basker's

statistical tables were used to check for significant differences between any two total preference-ranking scores of the samples (Lawless and Heymann, 1998).

4.4 Results and discussion

4.4.1 Carbohydrate content of potatoes

Table 4.1 shows that generally the sugar content of potatoes stored *in situ* and farmer's storage was significantly different from that of potatoes in controlled storage ($p < 0.05$). As expected, the potatoes in the controlled environment store contained higher sugar contents and potatoes *in situ* had the lowest sugar content. The LSD test indicated that type of storage significantly affected the total sugar content of the potatoes ($p < 0.05$) (Table 4.1). Higher sugar levels in potatoes from controlled storage were attributed to cold sweetening which starts at 10°C and increases as the temperature decreases, becoming more rapid below 7°C (Cheong and Govinden, 1998). Although the sugar content of potatoes in farmer's storage was often not significantly different from potatoes left *in situ*, the potatoes in farmer's storage generally contained more sugar. Since temperatures in the farmer's storage were higher (Figure 4.1), tubers tended to sprout faster (van Es and Hartmans, 1987). This may have contributed to the higher sugar levels in those potatoes as sugars may have been produced to support sprouting (van Es and Hartmans 1987; Sparenberg, 1987).

The effect of storage conditions on starch content of potatoes was not consistent. Published work on changes in starch content of potatoes in storage showed that starch loss ranged from 0.5 gkg⁻¹ in non-sprouting tubers to 2.0 gkg⁻¹ in sprouted tubers (Burton, 1989). Potatoes left *in situ* contained more starch than potatoes in traditional farmer's store and controlled storage (Table 4.1). Probably, during the first two weeks of storage, despite the fact that haulms were senescing at harvesting, translocation of sugars to the potatoes for storage in the form of starch did not cease.

Consequently, more starch may have been added to the tubers *in situ* during the first two weeks of storage. Leaving potatoes *in situ* may have had the benefit of improving the quality of the potatoes in terms of improved starch content and reduced sugar levels.

Table 4.1. Total sugar and starch content (g kg⁻¹, dry weight basis) of an organically grown landrace potato cultivar from three seasons left in situ, and stored in a farmer's store and in a controlled environment (7°C and 90% RH) over 2, 4 and 6 weeks

Season	storage	weeks of storage	Total sugar content [†]	Total starch content [†]	Total preference rank score [‡]
Summer	<i>In situ</i>	2	7.33a**	603.50a*	96a*
	Farmer	2	9.17a**	653.80b	141b
	Controlled	2	27.19b	656.58b	123b
		LSD _{0.05}	3.36	32.25	25.7
	<i>In situ</i>	4	5.77a***	536.33a**	100a*
	Farmer	4	7.97a***	617.07b	132b
	Controlled	4	69.91b	613.65b	128b
		LSD _{0.05}	3.68	23.99	25.7
	<i>In situ</i>	6	NDa***	603.06	95a*
	Farmer	6	11.99b	660.82	127b
	Controlled	6	16.30b	598.48	138b
		LSD _{0.05}	3.75	30.53	25.7
Autumn	<i>In situ</i>	2	14.14a***	578.85	97a*
	Farmer	2	27.46b**	577.76	138b
	Controlled	2	82.96c	525.04	125b
		LSD _{0.05}	6.23	33.25	25.7
	<i>In situ</i>	4	12.00a*	650.97a***	113
	Farmer	4	1.83b***	528.65b	127
	Controlled	4	71.18c	567.66b	120
		LSD _{0.05}	3.60	33.51	25.7
	<i>In situ</i>	6	0.00a**	730.22a*	99a*
	Farmer	6	1.83a**	649.67b	130b
	Controlled	6	20.57b	667.97b	131b
		LSD _{0.05}	3.55	48.63	25.7
Winter	<i>In situ</i>	2	0.00a***	731.95 a**	98a*
	Farmer	2	1.97a***	662.57b	138b
	Controlled	2	62.00b	659.42b	124b
		LSD _{0.05}	4.53	15.44	25.7
	<i>In situ</i>	4	0.00a***	703.05 a**	98a*
	Farmer	4	1.85a***	593.53b	139b
	Controlled	4	73.10b	614.02b	123ab
		LSD _{0.05}	4.15	20.99	25.7
	<i>In situ</i>	6	4.73a**	714.71 a**	92a
	Farmer	6	6.47a**	655.31b	132b
	Controlled	6	29.58b	625.01b	136b
		LSD _{0.05}	3.67	17.42	25.7

Significant difference exists between two samples within the same season and length of storage followed by different letters at ***p≤ 0.001, **p≤0.01 and * p≤0.05 levels. ND = not detected

[†]LSD test used to compare means

[‡]Basker's statistical tables used to compare preference rank totals

On the other hand, conversion of starch to sugars for respiration and to support sprouting in the farmer's storage and cold-induced sweetening in potatoes stored under controlled environmental conditions, reduced the starch content of these potatoes. Differences in sugar and starch content of the potatoes contributed to the differences in sensory preferences of potatoes from the three types of storage.

4.4.2 Sensory preference of potatoes

Table 4.1 shows that potatoes stored *in situ* were significantly preferred over potatoes stored in both the farmer's and controlled storage ($p < 0.05$) at all sampling times, except at four weeks in autumn. Although at four weeks, in autumn, preference scores were not significantly different; potatoes *in situ* were still more preferred to those from the traditional and controlled storage. Table 4.2 shows that *in situ* storage had the highest proportion (%) of potatoes given either a preference ranking score of one or either one or two.

Table 4.2. Table of means showing percentage of samples from *in situ*, farmer and controlled storage ranked either most preferred (1) or both most (1) and second most preferred (2) by panellists

Season	Storage method	% samples ranked 1		% samples ranked 1 or 2		
		N	Mean	Std. Dev.	Mean	Std. Dev.
Summer	<i>In situ</i>	3	55.55a*	6.94	82.78a*	4.20
	Farmer	3	22.22b	1.92	55.56b	10.05
	Controlled	3	22.22b	7.70	61.67b	6.01
Autumn	<i>In situ</i>	3	47.78a*	12.62	80.55a*	3.85
	Farmer	3	21.11ab	5.85	59.45b	3.85
	Controlled	3	31.11b	9.18	60.00b	0.00
Winter	<i>In situ</i>	3	56.67a*	4.41	83.33a*	1.67
	Farmer	3	17.22b	3.47	55.56b	4.19
	Controlled	3	26.11b	6.94	61.11b	5.36

* Percentages within the same season and sensory preference category that are not followed by the same letter are significantly different at $p < 0.05$.

The most frequent criterion (read from panellists' comments) used by panellists to decide on giving a sample a preference rank of 1 was that the sample was floury and had a good taste. On other hand a preference rank score of 3 was frequently given to a sample that was said to be bitter and/or had a soggy texture.

Correlation analysis indicated that, in general, total preference rank scores were negatively correlated to sugar content of the potatoes, and starch content was positively correlated with total preference rank scores (Table 4.3). Potatoes left *in situ* had higher starch content than those from the other types of storage. This probably contributed to the desirable floury texture in the potatoes.

Table 4.3. Table of Pearson's correlation coefficients of correlations between total sensory preference score and levels of sugars and starch in organically produced potatoes

Season	N	Length of storage	Total sugar content	Starch content
Summer	9	2	-0.19	0.81**
	9	4	-0.23	0.90**
	9	6	-0.79*	0.49
Autumn	9	2	-0.55	0.25
	9	4	-0.56	0.82**
	9	6	-0.19	0.20
Winter	9	2	-0.72*	0.52*
	9	4	-0.54	0.79*
	9	6	-0.59	0.60

Correlations were significant at ** $p \leq 0.01$ and * $p \leq 0.05$

Unexpectedly, potatoes from controlled storage, which had high sugar content ranked second while potatoes from farmer's storage generally ranked third. It was expected that the higher sugar content in the potatoes from the controlled storage would contribute to a soggy texture or a sweet taste (Burton, 1989) making them less desirable to panellists. Since, as has been stated already, a preference rank of 3 was also associated with bitterness, potatoes from farmer's storage may have contained

bitter substances. Probably, the bitter substances were glycoalkaloids. Exposure to natural light and high temperatures has been associated with increased levels of glycoalkaloids in potatoes (Salunkhe, Wu and Jadhav, 1972; Şengül, Keleş and Keleş, 2004; Percival, Dixon and Sword, 1996). As has been stated earlier, potatoes in traditional storage were inadvertently exposed to indirect sunlight during the day. A study by Machado, Toledo and Garcia (2007) showed that total glycoalkaloid content of potatoes stored for two weeks in indirect sunlight increased from 51.4 to 92.5 mg kg⁻¹, on fresh weight basis (Mondy and Gosselin, 1988).

Glycoalkaloids α -choconine and α -solanine typically account for approximately 95% of total glycoalkaloid content (TGA) of potatoes and are not destroyed by ordinary cooking (Şengül, Keleş and Keleş, 2004). During cooking, glycoalkaloids often concentrated in the outer 1.5 mm of the tubers (Wszelaki *et al*, 2005), migrate into the inner tuber flesh affecting its taste (Griffiths, Bain and Dale, 1997). Increase in the glycoalkaloid content may also have affected the taste of potatoes stored under controlled environment conditions. Machado, Toledo and Garcia (2007) and Griffiths, Bain and Dale (1997) reported increases in glycoalkaloid content of potatoes stored between 7-8°C in darkness compared to potatoes stored in darkness at room temperature (19-26°C). In this study, leaving potatoes *in situ* provided conditions of darkness and temperatures similar to room temperatures in the above mentioned study. Low TGA content in potatoes left *in situ* may be one of the reasons why panellists rated these samples as better tasting.

4.5 Conclusions

This study shows that *in situ* storage preserved desirable qualities in potatoes. Because potatoes left *in situ* had a low sugar and high starch content, they appeared to have maintained a good texture and taste and, were most preferred over potatoes from the other types of storage. Sensory evaluation results show that potatoes left *in situ* were preferred to those from the traditional house and controlled storages. An inconsistent relationship between carbohydrate content and sensory preference indicates that additional factors may have contributed to the sensory characteristics of the potatoes, particularly those in traditional storage. Glycoalkaloid content of the potatoes, not investigated in this study may have played a role in the sensory quality

of the potatoes. It is recommended that future research should include analysis of glycoalkaloid content and textural characteristics of potatoes.

However, this study has shown that sequential harvesting ensures that potatoes retain desirable sensory and carbohydrate content characteristics. This finding is important for resource-poor small scale organic farmers as it points to a seemingly efficient storage option where other storage methods and technologies may be inappropriate, ineffective or unaffordable. Further investigation needs to explore the consumer quality expectations for organically grown potatoes and whether sequentially harvested potatoes meet these expectations. Research to explore the effect of sequential harvesting on the sensory quality of potatoes is necessary.

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CHAPTER 5: CAN SEQUENTIAL HARVESTING HELP SMALL HOLDER ORGANIC FARMERS MEET CONSUMER EXPECTATIONS FOR ORGANIC POTATOES?

5.1 Introduction

Emerging organic niche markets provide an important incentive for small scale farmers to commercialise production of potatoes. Organic food markets provide small scale farmers with opportunities for higher income due to premium prices (Baecke *et al*, 2002; Gifford and Benard, 2006). Many South African subsistence farmers, like those of the Ezemvelo Farmers Organisation (EFO), are strategically positioned to benefit from organic production because they typically practice traditional farming akin to organic farming (Modi, 2003).

Despite providing opportunities for small scale farmers to increase production and incomes, quality requirements may push small scale farmers out of the market (Dries, Reardon and Swinnen, 2004; Reardon and Berdegué 2002). Maintenance of post harvest appearance quality in perishable horticultural products like potatoes, supplied on demand to supermarkets, depends on the effectiveness of storage methods used. Horticultural products are expected to maintain desirable appearance characteristics such as firmness, ripeness and absence of blemishes (Berdegué *et al*, 2005).

Kilcast (2006) emphasises the importance of research to understand perceptions and needs of consumer populations that special products target. Consumers may have different expectations and acceptance of the same food product produced using different technologies (Mireaux *et al*, 2007). Acceptance of a food product depends on consumers' understanding and perception of the technology, the exact process involved and its perceived benefits or consequences (Mireaux *et al*, 2007). Although there have been investigations of consumer purchase motivations for organic products including potatoes (Joansson *et al*, 1999; McEachern and McLean, 2002; O'Donovan and McCarthy, 2002; Wszelaki *et al*, 2005), consumer expectations of organically grown potatoes in South Africa has not been studied. Research is needed to shed light

on how traditional storage methods can be used to retain desirable attributes (as identified by consumers) in organically grown potatoes.

Potatoes are stored in a fully hydrated, highly perishable form and are subject to quality losses caused by microbiological, physiological and environmental factors (Burton, van Es, and Hartmans, 1992; Dahiya *et al*, 1997; Sparenberg, 1987; Suttle, 2004). Faced with lack of appropriate storage technologies, small scale farmers use relatively simple storage systems based on indigenous knowledge that often lead to substantial quality losses (Mughogho, 1989). On the other hand, traditional storage may be organically compliant, affordable and culturally appropriate alternative to conventional storage. It is important to understand consumer quality expectations in order to assess the effectiveness of traditional storage practices in retaining quality, especially for small scale farmers participating in formal competitive markets.

The previous chapter showed that sequentially harvested potatoes maintained desirable sensory properties due to lower sugar levels and higher starch content compared to cold storage and farmer's store. However, within sequential harvesting, potatoes harvested at different times may have different sensory and post harvest keeping qualities.

The objectives of this chapter are to determine: the consumer quality expectations of organically and conventionally grown potatoes; the effect of traditional storage methods on consumer expected quality of organic potatoes and the effect of sequential harvesting on sensory and keeping quality of potatoes grown by small scale organic farmers in Embo.

5.2 Research methodology

A consumer survey was conducted at an annual Garden Show in Pietermaritzburg South Africa, in September, 2004. A total of one hundred respondents (63 female and 37 male) were interviewed. Participation was voluntary and respondents were sampled on the basis of their willingness to participate. Most respondents (67%) were aged between 25 and 60. Seventeen and 16% were aged between 20 - 25 and over 60 years respectively. Respondents were asked to select the appearance qualities looked

for when purchasing potatoes; what size potatoes they typically purchased and how long they expected potatoes to store post purchase. Consumers were also asked to state whether and why they purchased organic potatoes and to comment on quality differences expected between organically and conventionally grown potatoes.

The farmer survey was conducted in October and November 2004. A list of EFO members was compiled from certification records held at the University of KwaZulu-Natal and records of the EFO executive. EFO members comprised 123 partially certified and 48 fully certified organic farmers. Data was collected from 101 farmers who grew potatoes organically; 48 fully certified farmers and 53 partially certified farmers. In the survey, the farmers' storage practices were identified and the main forms of potato quality losses in storage were studied. Additional data on storage practices was collected through in-depth interviews with three farmers who, together with the researcher, formed a co-research group. The co-research group was vital in the identifying important traditional methods to be included in the potato storage experiment; understanding of and adherence to farmer practices in relevant aspects of the experiment; and to facilitate transfer of research findings to EFO members as established by Ashbey *et al* (2000). In-depth key informant interviews were also conducted with the chairperson of the EFO, a seasoned organic farmer who provided information on potato production, quality management and marketing logistics.

Potatoes were grown, harvested and stored in farmer's store and left *in situ* as described in the methodology in Chapter 4. The co-research group identified farmer's store (storage on the floor in a farmer's hut) and sequential harvesting as the main storage methods used by the farmers which needed to be studied to ascertain their effectiveness.

Potatoes were sorted to remove all damaged, rotting, sprouted and greening potatoes. Potatoes of unacceptable quality were counted, recorded and expressed as a percentage of total baby potato tubers harvested. This was repeated during the fortnightly observation of potatoes in storage.

Traditional huts with earthen floors were primarily used as farmer's stores. The huts were round, with walls constructed from mud and mud bricks and thatched or roofed

with metal sheets overlaying a layer of closely packed sticks or grass that acts as an insulator. There was a space between the roof and the wall that acted as a vent and lighting was mainly through the door, when opened. The units were not purposely built for potato storage. Apart from storing potatoes, they were also used as bedrooms, dining rooms and for storage of implements and other produce. Due to the multi-purpose nature of the hut, the door was opened several times in a day, exposing potatoes to indirect sunlight. In typical farmer's stores, potatoes are loosely spread on the floor, but in this experiment, potatoes were loosely packaged in nylon net bags before storage for containment and to facilitate sampling during observations.

In sequential harvesting, the farmers left potatoes *in situ* after maturity, harvesting varying quantities as and when they needed the potatoes for food or for sale. The potatoes were harvested by rows. It was reported that farmers left the potatoes for ± 6 weeks depending on the need to use the piece of land in question and quality changes in the produce due to sprouting, pest damage and rotting. In this experiment potatoes were harvested at two week intervals from the time of crop maturity (i.e. 0 weeks, 2 weeks, 4 weeks and 6 weeks).

The percentage of produce lost due to quality deterioration in the *in situ* and farmer's store was recorded during the two weekly observations. Potatoes of unacceptable quality in the farmer's store were removed at the end of each observation event to prevent further contact between deteriorating and healthy tubers in storage. Losses *in situ* and storage were assumed to progress comparably because of the assumption that there was no contact between healthy and rotting tubers *in situ*. Additional losses in both storage methods were ascribed to storage conditions and previous contamination. Losses were quantified cumulatively. Losses quantified during the two weekly observations of potatoes in farmer's store were added to previous losses and expressed as a percentage of the initial weight.

To investigate the effect of time of harvesting on post harvest dormancy of potatoes, thirty potatoes were sampled after each harvest for dormancy testing. Potatoes were stored with the apical eye up on a thin layer of sterilized dried sand in a chamber in complete darkness at 18°C and 90% relative humidity (Krijthe, 1962 cited in Burton, van Es and Hartmans, 1992). A potato was considered to have sprouted if it bore a

sprout of ≥ 2 mm in length (Lommen, 1993; Suttle, 1998). Sprouting was assessed visually weekly (Suttle, 1998). The time it took for 50% of the potatoes to sprout constituted the dormancy period of the potatoes (Lommen, 1993).

To determine the effects of sequential harvesting on sensory qualities of potatoes, forty potatoes were sampled after each harvest. After washing them to remove dirt, the potatoes were blanched unpeeled for about 10 min in boiling water at 95°C and then immediately dipped in ice cold water to lower the temperature to 1°C. The potatoes were then drained, dried and stored at 1°C in darkness until a week after the final harvest. This allowed consistent treatment across harvests. After the last week of storage, sampled potatoes were steamed for approximately 20 minutes, until a kitchen fork penetrated easily. While warm, the cooked tubers were cut in half along the bud stem axis and presented to 60 volunteer panellists for sensory evaluation as described in section 4.2.2. of Chapter 4. Panellists were asked to rank the samples from the most preferred (1) to the least preferred (4).

5.3 Data analysis

Data was analysed using SPSS release 13.0 (SPSS Inc., Chicago, Illinois). Descriptive statistics on potato size preferences, storage period expectations and quality characteristics used in selecting potatoes to purchase were computed. Multiple response analysis was used for computing frequencies of appearance quality characteristics used by consumers in selecting potatoes to purchase. Chi-square tests were used to explore differences in storage problems reportedly experienced by farmers who did and those who did not practice sequential harvesting. Analysis of variance was used to determine the significance of changes in potato quality losses *in situ* and in farmer's store and in dormancy period of sequentially harvested potatoes.

5.4 Results and discussion

5.4.1 Consumer and supermarket quality expectations

Thirty-five per cent of the respondents of the consumer survey were organic potato consumers. The consumers interviewed felt that organic potatoes were tastier (84.3%), more nutritious (54.9%) and contained no chemical contaminants (54.9%).

In addition, 49% of participating consumers purchased organic potatoes in support of sustainable agriculture. Forty-nine per cent of consumers purchased both baby and larger potatoes, while 13% and 38% preferred baby and larger potatoes respectively. Absence of greening emerged as the most important characteristic used by both organic and conventional potato purchasers (Table 5.1).

Table 5.1: Appearance quality attributes used by potato consumers when purchasing potatoes in Pietermaritzburg, 2004

Appearance quality attribute	Per cent consumers interviewed ^a	
	Organic (N = 35)	Conventional (N = 65)
No greening	88.6	87.7
No sprouting	80.0	84.6
Smooth skin texture	71.4	67.7
No skin blemishes	65.7	76.9
Light Skin colour	40.0	41.5

^a Multiple responses were allowed, therefore, the sum of percentage values do not equal 100%

Sixty-one per cent of organic potato consumers interviewed indicated that they did not expect the appearance of organic potatoes to be different from conventionally grown potatoes. However, 39.4 % of organic potato consumers did not expect organic potatoes to be as perfect in appearance, in terms of skin texture and colour, as conventional potatoes. Organic potato consumers interviewed (71%) expected no differences in the cooking quality. There were no differences in storage expectations as 94% of both conventional and organic potato consumers expected potatoes to store up to four weeks post purchase (Table 5.2).

Table 5.2: Consumer expectation of the storage life of organic and conventional potatoes in Pietermaritzburg, 2004

Expected storage life (weeks)	Per cent consumers (cumulative)	
	Organic (N = 35)	Conventional (N = 65)
1	31.43	30.43
2	48.57	63.77
3	74.29	75.36
4	94.29	94.20
6	97.14	95.65
8	100	100

The qualities used by the pack house and the supermarket chain were similar to those used by consumers in selecting potatoes to purchase (Tables 5.1 and 5.3). It took the pack house three days to process, package and dispatch the potatoes to the supermarket chain. In the retail shop, the potatoes were kept on the shelf for up to four days (Woolworths Quality Management System, 2004), making a total of one week from the time potatoes were procured from the farmers.

Table 5.3: Potato quality expectations of the supermarket to which the farmers sell (Woolworths Quality Management System, 2004)

Quality specification	Description of desired qualities
Size	Baby potatoes: 15 g to 60 g
Colour	Light tan; clean, free from attached earth, no greening potatoes allowed
Firmness	Should not be soft and wilted
Blemishes	No silver scurf, black scab and netted scab affecting appearance. Mechanical damage, external or internal disease/physiological damage not allowed. Sprouting tubers not allowed
Shelf life	4 days and nights in stores

5.4.2 Farmer storage practices

Of the 101 farmers who grew potatoes, 55% practiced sequential harvesting (Table 5.4). Storage problems were the main reason for practicing sequential harvesting. Additionally, sequential harvesting helped farmers to spread their income and acted as a form of savings which enabled farmers to get income from selling to local buyers at opportune times. However, for premium prices the farmers sold to the pack house on demand according to amounts required by the pack house. This made it impossible in some cases for farmers to sell all their produce at once. Postponing harvesting also

enabled the farmers to smooth labour demands. Given the labour scarcity and costs in the area, sequential harvesting enabled the farmers to use household labour more efficiently amongst different crops and activities. Farmers also reported financial savings due to minimal use of hired labour for potato harvesting.

Farmers who did not practice sequential harvesting spread potatoes on the floor of huts for long term storage - between four to eight weeks post harvest. However, farmers complained that the potatoes sprouted quickly and greened in storage, making them unacceptable for sale to the pack house (Table 5.4). Sprouting potatoes were used for household consumption and were sold locally at reduced prices for food and as seed stock.

Table 5.4: Association between reported storage problems experienced by small scale organic potato farmers and practice of sequential harvesting using chi-square tests, Embo, 2004

Storage problem	Practice sequential harvesting?		Chi-Square value
	% farmers: Yes (n=55)	% farmers: No (n=46)	
Sprouting	41.82	41.30	1.23
Rotting	78.18	71.74	0.51
Greening	32.73a	69.57b	6.74
Insect damage	25.45	17.39	0.80
Shrinking	16.36a	54.35b	6.88

Values in the same row followed by different letters are significantly different at *p<0.01

5.4.3 Effect of storage on potato quality loss

There was some increase in produce losses in later harvests in all three seasons. However, analysis of variance results showed significant increase in crop losses when potatoes were left *in situ* for extended period of up to six weeks post maturity in autumn and winter. Highest proportions of potatoes of unacceptable quality in sequentially harvested potatoes were noted in summer. An average of 32.74% of tubers harvested in summer was of unacceptable quality compared to averages of

6.27% of autumn and 7.73% in winter. This was mainly due to problem of soft rot in summer because of higher temperatures and wet conditions (Toth *et al*, 2003). Soft rot was the main form of loss in all seasons. Other quality problems included greening, pest damage and sprouting. The main pest damage observed was from millipedes and nematodes. Generally, sequential harvesting resulted in significantly ($p \leq 0.05$) lower potato losses than farmer's store in all seasons.

The farmer's store had a higher cumulative potato loss (Table 5.5). Potatoes stored in the farmer's store had a larger proportion of greening and sprouting potatoes. Exposure to indirect sunlight resulted in greening of potatoes rendering them unacceptable to consumers.

Table 5.5: Effect of sequential harvesting and storage in farmer's store on potato losses due to quality deterioration in Embo, 2004-2005

Season	Length of storage (weeks)	N within Storage method	F	<i>In situ</i>	Std	Farmer's store	Std
				% loss ^a	error	% loss ^a	error
summer	0	3	0.00	31.15	0.31	31.15	0.31
	2	3	76.13	31.27a	0.54	38.90b ^{***}	0.69
	4	3	316.27	31.83a	0.22	42.56b ^{***}	0.56
	6	3	322.98	32.06a	0.58	45.96b ^{***}	0.52
Autumn	0	3	0.00	4.44	0.55	4.44	0.55
	2	3	12.37	4.45a	0.13	13.78b [*]	2.65
	4	3	68.50	5.36a	0.12	17.14b ^{**}	1.42
	6	3	4643.66	8.31a	0.05	20.86b ^{***}	0.18
Winter	0	3	0.00	4.28	0.08	4.18	0.08
	2	3	638.50	7.02a	0.12	10.46b ^{***}	0.06
	4	3	2762.50	8.31a	0.05	11.17b ^{***}	0.02
	6	3	577.13	11.31a	0.07	37.05b ^{***}	1.08

^aMean per cent losses in the same row followed by different letters are significantly different at * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$

5.4.4 Effect of sequential harvesting on potato dormancy

Generally, potatoes harvested earlier took longer to sprout post harvest than those harvested later (Table 5.6). This confirms the observation by Bruinsma and Swart (1970) that the later the lifting takes place, the shorter the dormancy period. Season, harvesting time and the interaction between these two factors had significant effect on the time potatoes took to sprout at 18°C ($p < 0.001$).

Table 5.6: Effect of time of sequential harvesting on potato dormancy, Pietermaritzburg, 2004-2005

Time of harvesting	N	Summer Dormancy (weeks)	Std error	Autumn Dormancy (weeks)	Std error	Winter Dormancy (weeks)	Std error
0 weeks	3	11.00a*	0.58	12.67a*	0.33	7.67a*	0.33
2 weeks	3	9.33a*	0.67	10.67b*	0.67	4.67b*	0.33
4 weeks	3	7.00b	0.58	7.33c	0.33	3.67c	0.33
6 weeks	3	5.33b	0.33	6d	0.58	3.00c	0.00

Values in the same column followed by different letters are significantly different at $*p < 0.05$

5.4.5 Effect of sequential harvesting on sensory qualities of potatoes

Since sequential harvesting was seen to reduce post harvest losses, potatoes from different harvesting times were compared to check if harvesting time did affect sensory properties. Potatoes harvested at different times did not show significant differences ($p < 0.05$) in terms of sensory qualities. Potatoes left *in situ* retained good sensory qualities and were well accepted by consumers (Figure 5.1). The preference rank sums of potatoes harvested six weeks after the crop was ready for harvesting (142 in summer, 144 in autumn and 140 in winter) were comparable to potatoes harvested at zero weeks of storage (156 in summer, 153 in autumn and 152 in winter). According to Basker's table, critical value of difference between rank sums at $p < 0.05$ for four samples, using 60 panellists is 36.3 (Lawless and Heyman 1998).

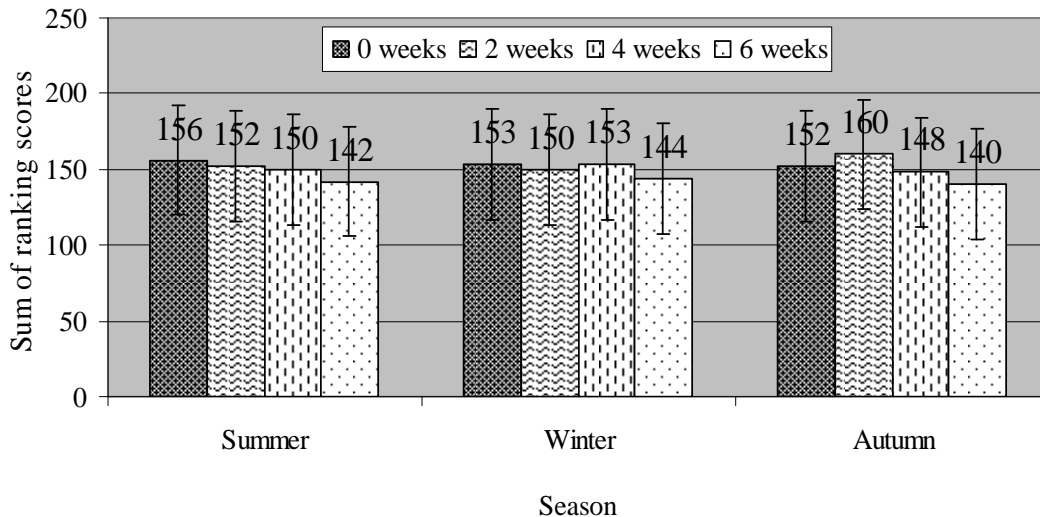


Figure 5.1: Effect of harvesting time on the sensory quality of potatoes as shown by preference ranking scores.

5.4.6 Can sequential harvesting help smallholder organic farmers meet consumer expectations for organic potatoes?

This study has shown that the reasons consumers purchase organically grown potatoes in Pietermaritzburg, South Africa are similar to those presented by other studies in other countries. Organic consumers are motivated by health, taste, food safety and environment conservation (Lockie *et al*, 2002; Makatouni, 2002; McEachern and McClean, 2002; Moore, 2006; O'Donovan and McCarthy, 2002). The results have also revealed a high demand for baby potatoes among consumers of organically grown potatoes. Baby potato growers can be assured of a sizeable market for their produce. The increase in demand for organically grown foods in South Africa potentially presents a growing market for this product (Business Times, 2004; Darroch, 2001).

The consumers ranked greening as the most important factor in determining which potatoes to purchase. Potato tuber greening is associated with the development of glycoalkaloids which at certain concentrations impart a bitter flavour, cause sickness and even death (Grunenfelder, Hiller and Knowles, 2006; Morris and Lee, 1984; Phlak and Sporns, 1992). Consequently, both marketers and consumers avoid purchasing greening potatoes. As seen from table 5.2, similar proportions of organic and conventional consumers reported using the different appearance characteristics in

purchasing potatoes. Similarly, the potato keeping quality expectations of organically and conventionally grown potato consumers were not different. This suggests that the fact that produce is grown organically does not compensate for poor quality. Tsotsou (2006) notes that purchase intentions and satisfaction of consumers are affected by both perceived and objective quality. Producers of organic potatoes need to ensure that produce meets quality standards just like conventionally grown potatoes. This poses a challenge, especially for small scale farmers with no access to organically approved chemicals and modern post harvest handling methods that preserve quality.

Leaving potatoes *in situ* resulted in reduced losses compared to harvesting and storing potatoes using farmer's store. This finding is similar to that of Smit's (1997) study of piecemeal and sequential harvesting in sweet potatoes in Uganda. Smit's (1997) study also showed that sequential harvesting had lower losses compared to prompt harvesting followed by storage.

In this study, sequential harvesting maintained both the keeping and sensory quality of the potatoes. The majority of consumers expected to store potatoes for up to four weeks post-purchase. With the addition of one week processing time; in terms of sprouting, the keeping quality of sequentially harvested potatoes was acceptable especially in summer and autumn. In winter, the potatoes harvested four to six weeks later had a shorter shelf life, 3.67 and three weeks respectively. However, this keeping quality was still within the acceptable range, since 74% of organic potato consumers stored potatoes for up to three weeks post purchase (Table 5.2). The sensory preference of potatoes harvested six weeks after commencement of harvesting was not significantly different from those harvested immediately after maturity.

The use of sequential harvesting to maintain the quality of root crops is not limited to potatoes. Among the farmers in the study area, sequential harvesting is also practiced on taro (*amadumbe*) and sweet potatoes. Although studies on the effect of sequential harvesting have not been conducted on these crops, the sequentially harvested produce was seemingly of acceptable quality to consumers. Studies may need to be conducted on these and other tuber crops to establish how long the crops can be left *in situ* without compromising the quality of the crops.

5.5 Conclusion

Consumers in the study highlighted five desirable characteristics in potatoes: absence of greening, absence of sprouting, smooth skin texture, absence of blemishes and light skin colour. No significant differences in the quality expectations between participating organic and conventional potato consumers were found. Consumers generally expected potatoes to store for up to four weeks post purchase. Two major traditional storage practices were used by farmers: sequential harvesting and traditional storage. Storage in the farmer's store resulted in higher post harvest losses than sequential harvesting. After six weeks of storage, potatoes *in situ* maintained good appearance and sensory qualities. Unlike sequential harvesting, losses from potatoes stored using farmer's store increased significantly over the six weeks of storage mainly due to greening from exposure to indirect sunlight.

The findings have shown that consumers of organic and conventional potatoes have similar quality expectations for potatoes. Producers therefore need to identify organic-compliant post harvest handling practices that retain acceptable produce quality or practice sequential harvesting. Sequential harvesting seems to provide resource-poor small scale organic farmers with an efficient storage option where other storage methods and technologies may be inappropriate, ineffective or unaffordable. It would seem that this technique could be applicable to other root crops like sweet potatoes and taro (*madumbe*). However, studies need to be undertaken to ascertain the effect of sequential harvesting on the sensory qualities of these crops because repeat purchases of produce is dependent on experienced quality after consumption. There is also need to ascertain the economic benefits of sequential harvesting. Does the quality loss in storage mean revenue loss for the small scale farmers? What constituted the losses and can or do farmers have alternative lucrative uses for produce that can not be sold to niche markets? The next chapter looks to answering these and other related questions.

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CHAPTER 6: DOES QUALITY LOSS IN STORAGE RESULT IN SIGNIFICANT REVENUE LOSS FOR SMALL SCALE ORGANIC FARMERS?

6.1 Introduction

Agriculture remains an important contributor to the rural economy in South Africa contributing between 10 and 20% of household income for rural small scale farmers (Hendriks and Lyne 2003). Small scale farming is typically practised in the former homelands that account for 14% of farmland in South Africa (Bekker, 2003; Machehe and Ortmann, 2003; Orkin and Njobe, 2000). Potatoes are one of the important horticultural crops grown by small scale farmers for both cash and food. In a study in Umbumbulu, KwaZulu-Natal, Ndokweni (2000) found that organically grown potatoes were the third most important cash crop for small scale farmers after *amadumbe* and sweet potatoes.

Potato production, like all crop production, is a risky venture. Diseases, pest damage and deterioration due to use of inappropriate storage methods may easily rob small scale farmers of much needed returns from investment (Burton, van Es and Hartmans, 1992; Larkin and Griffin, 2007; Stevenson *et al*, 2001 and Suttle, 2004). This risk is relatively higher for small scale organic farmers because of the restrictions on use of synthetic chemicals to curb pests and diseases. Consequently, controlling diseases and pests both in the field and in storage is challenging (Rundgren, 2004). In addition, lack of access to pest and disease-free seed may limit the effectiveness of other measures to reduce the incidences of diseases (Stead, 1999).

Although storage can help farmers keep produce until market prices are favourable, storage itself is risky (Fuglie, 1999). Potato produce losses in storage may be caused by diseases, pest damage, sprouting, greening and desiccation that reduce income (Burton, van Es and Hartmans, 1992; Larkin and Griffin, 2007; Stevenson *et al*, 2001; Suttle, 2004). Although consumers of organic produce are often supporters of environmentally friendly production, they are also typically quality and food safety conscious (Kirsten and Sartorius, 2002). Organic farmers need to ensure that produce is of acceptable quality to the consumer to meet the criteria for premium prices. In

Chapter four and five it was demonstrated that sequential harvesting (*in situ* storage) preserved the sensory quality of organic potatoes better than other storage methods. Similarly, *in situ* storage may result in less storage losses compared to storage in a farmer's store.

Despite the fact that greening, pest damaged and sprouting potatoes are not sold to food markets at a premium price, this produce translates into economic loss if farmer derives no benefits from the produce. In some cases, low grade produce may be put to profitable economic use: for example juice, fruit bar and jam making in fruits (Ghosh, 2004). Possible uses of low grade potatoes include, use as planting materials, home food or dried chips. This chapter investigates the produce losses experienced by small scale organic farmers at harvest and during storage. Three storage methods (leaving potatoes *in situ*, storage in farmer's store and controlled storage) were compared in terms of the types and quantity of produce losses. The paper also investigates whether, and which, quality losses constitute economic losses. Ways to minimise the losses are discussed.

6.2 Research methodology

A farmer survey was conducted in October and November 2004 as described in section 5.2. During the two-year study, the researcher also observed, participated in and documented farmer practices. Potato production, harvesting and storage were done as described in methodology sections of chapters 4 and 5.

6.2.1 Determination of weight losses in storage

The percentage of produce lost due to quality deterioration in the three storage facilities were recorded during two weekly observations. Potatoes of unacceptable quality were removed at the end of each observation to prevent further contact between deteriorating and healthy tubers in storage. Losses *in situ* and storage were assumed to progress comparably because of the assumption that there was no contact between healthy and rotting tubers *in situ*. Additional losses in all the storage methods were ascribed to storage conditions and previous contamination. Losses were quantified cumulatively. Losses quantified during the two weekly observations of potatoes in controlled and farmer's store were added to previous losses and expressed as a percentage of the initial weight. Desiccation losses were only calculated in the

controlled and farmer's store because it was difficult to determine this type of loss *in situ*. Losses due to pest damage and rotting were combined because in some instances it was difficult to distinguish between them and because the clear cut pest damage losses which only occurred *in situ* were negligible. Potato greening was assessed visually using a scale similar to the one in Figure 6.1.

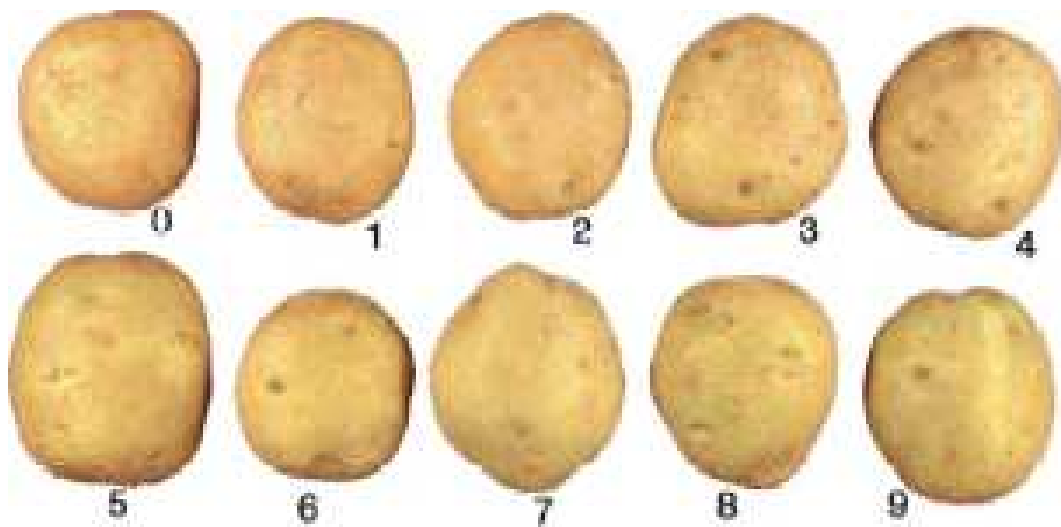


Figure 6.1: Scale used to classify potatoes of unacceptable quality due to greening; potatoes ranked from 7 upwards are not acceptable for sale (Grunenfelder, Hiller, and Knowles, p 76, 2006).

Potatoes with visible greening like number 7, 8, 9 or more (Figure 6.1) were classified as unacceptable for sale. This was consistent with the farmer sorting practices based on the demands of their market. According to the regulations relating to the grading, packing and marking of potatoes intended for sale in South Africa, potatoes are unacceptable for class one if the greening covers more than 10% of the potato, i.e. number 8 and above in Figure 6.1 (National Department of Agriculture, 2005).

Preliminary identification of diseases in the tubers was done through symptom observation. Suspected diseases in the potatoes were potato scab (*Streptomyces scabies*), Fusarium dry rot (*Fusarium solani*) and Erwinia soft rot (*Erwinia carotovora*).

To confirm the presence of *S. scabies*, a method prescribed by Schaad, Jones and Chun (2001) was used and is described below. The infected tubers were surface disinfected in 1.5% NaOCl for one min and rinsed three times with sterile distilled water. Diseased portions of the potatoes (straw coloured tissue) were macerated using a mortar and pestle and allowed to stand for 10 minutes. A drop of this suspension was spread on Nystatin Polymyxin Penicillin Cycloheximide (NPPC) water agar. The plates were incubated for 12 days at 30⁰C before the colonies were transferred to NPPC Yeast Malt Extract (YME) agar. Colony observations using Primostar Carl Zeiss light microscope (Göttingen, Germany) at X1000 magnification revealed filamentous, ash-grey monopodial branching mycelium with spiral spore chains typical of *S. scabies*.

Fusarium solani was identified using the method recommended by Nelson, Toussoun and Marasas (1983). Infected tubers were surface sterilized using 1.5% NaOCl for one to three minutes, washed three to five times with sterile distilled water and damp-dried on absorbent towelling paper. A sample from the diseased material was then placed on Potato Dextrose Agar (PDA) and incubated at 26⁰C for seven days. Cream and blue coloured colonies characteristic of *Fusarium solani* on PDA were observed.

To investigate the presence of soft rot caused by *Erwinia carotovora* pv. *Carotovora*, the methodology according to Lacy and Lukezic (2004) was followed. Potato tubers showing soft rot symptoms were cleaned then crushed using a mortar and pestle. Sterile distilled water (15 ml) was added to the crushed sample. A sample from the resulting solution was then plated using the spread plate technique on Raffinose Selective Medium (RSM) followed by incubation at 28⁰C for one to two days (Segall, 1971). Red raised colonies characteristic of *Erwinia carotovora* on RMS were observed.

The main pests suspected in the potatoes were millipedes and nematodes. Millipedes were identified visually. Potatoes with pimple-like and warty-looking swellings were examined ascertain nematode infestation. The Mist extraction method as described by Shivas et al (2003) was used to extract nematodes from the potatoes (Figure 6.2).

Washed potatoes were cut into 1.0 cm to 1.25 cm cubes. A sample of approximately 10 g was placed per funnel and sprayed with water for five days. The organisms at the base of the funnel stem were collected and observed under a Primostar Carl Zeiss light microscope (Göttingen, Germany).

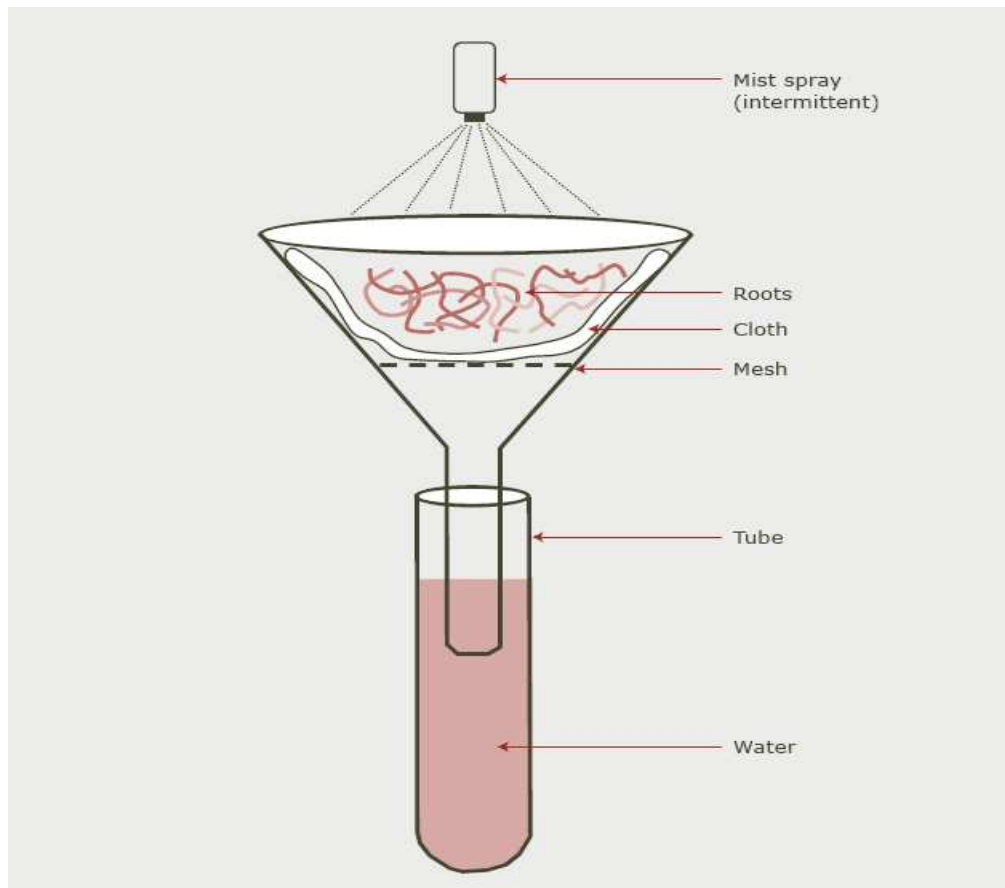


Figure 6.2: Mist extraction of nematodes from plant tissue (Shivas et al, p 38, 2003)

6.3 Data analysis

Analysis of variance using SPSS release 13.0 (SPSS Inc., Chicago, Illinois) was used to test for significant differences in cumulative losses from different causes in controlled storage, farmer's store and from produce left *in situ*. Independent samples t-test was used to determine if there was a significant difference in storage problems between farmers who practiced and those who did not practice sequential harvesting (leaving potatoes *in situ*). Additional information provided by the farmers is also presented in relevant sections of this chapter.

6.4 Results and discussion

6.4.1 Farmer production practices

Potatoes were produced three times in a year. The majority of potatoes were baby potatoes (< 50 g) sold to a niche organic market at a set annual price. At the time of this study the set price for the sale of potatoes to the pack house was R3.50 kg⁻¹. Seed potatoes of this landrace cultivar were sold at an average price of R3.00 kg⁻¹ in the community. The farmers considered the potatoes a traditional cultivar. The cultivar was passed down from generation to generation since potatoes were introduced to the community early in the twentieth century (Makhanya, 2005).

Due to the limited field sizes, the farmers generally practised a one year rotation cycle i.e. after a one year break, a field previously used to grow potatoes could be used to produce potatoes again. However, volunteer potato plants that came up were not necessarily uprooted from the fields. The volunteer potato plants provide a breeding ground for pests and diseases that infest the next potato crop and negatively affect quality and yield. Pests and diseases were also spread by seed potatoes.

The EFO farmers generally selected seed from their own produce or bought seed from neighbours. Farmers believed that consumers perceived the cultivar as a uniquely flavourful, tasty and nutritious and were reluctant to change to other cultivars. There was no farmer producing seed potatoes following recommended practices that ensure healthy seed stock without pests and diseases (Allen, O'Brien and Firman, 1992). This means that the potatoes used as seed could easily pass on pests and diseases from one farmer to the other. Potatoes of unacceptable quality due to slight rotting, greening, sprouting, small size and desiccation were generally used as seed. This practice increased the likelihood of the seed potatoes being a carrier of pests and diseases.

Seed potatoes were stored on the ground in the open, in sacks and/or buckets. Storage in sacks and in buckets sometimes resulted in rotting due to cross contamination and creation of anaerobic conditions. This resulted in reduced quantity of seed tubers and use of infected tubers as seed.

6.4.2 Causes of produce losses as identified by farmers

The farmers identified a number of problems leading to a reduction in the quantity of produce for sale or for own consumption. The problems included disease and pest damage, greening and sprouting. Table 6.1 shows results of an independent samples t-test to compare the proportions of farmers experiencing different storage problems on the basis of practicing and not practicing sequential harvesting. Significantly fewer farmers who practised sequential harvesting (*in situ* storage) reported potato losses due to greening and shrinking compared to farmers who did not use sequential harvesting. There were no significant differences in sprouting, rotting and millipede damage reported by the farmers. The results suggest that leaving potatoes *in situ* preserved desirable qualities in the potatoes. The main pest reported by the farmers was millipedes.

Table 6.1: Comparison of storage problems reported by farmers who did and those who did not practise sequential harvesting (Embo, November 2004)

Storage problem	% farmers using sequential harvesting	% farmers not using sequential harvesting	df	Std Err
Sprouting	41.82	41.30	99	0.10
Rotting	78.18	71.74	99	0.09
Greening	32.73a***	69.57b	99	0.09
Millipede damage	25.45	17.39	99	0.08
Shrinking	16.36a***	54.35b	99	0.09

Statistically significant differences exist between values in the same column followed by different letters at ***p<0.001

6.4.3 Losses in storage as determined experimentally

The storage losses were categorised into losses due to rotting and pest damage, sprouting, desiccation and greening. Table 6.2 shows results of produce losses incurred in summer, autumn and winter. Higher losses were experienced in summer and in the farmer's store.

The highest proportion of total loss in all seasons and methods of storage was from disease and pest damage (with the exception of winter beyond four weeks of storage). There was a highly significant correlation between season, total produce loss and produce loss due to pests and diseases (Table 6.2). In winter, the main cause of losses, especially beyond four weeks of storage, was sprouting.

Millipedes were observed during harvesting (Figure 6.3). The millipedes ate portions of the potato making large holes that rendered the potatoes unacceptable for sale. The millipedes were a bigger problem with the summer crop and the autumn crop. Further the millipedes facilitated the infection of potatoes with diseases such as soft rot and fusarium dry rot. The farmers expressed despondency in dealing with the problem of millipedes in an organic production system. Biological control using millipede assassin bugs, *Ectrichodia crux*, as suggested by Visser (2005), presents an important option to mitigate the impact of millipedes in the potato fields for the small scale organic farmers in Embo. *Ectrichodia cruxes* are bugs that feed exclusively on millipedes and are not known to pose any risks when used. Like millipedes, these bugs usually emerge at night or on overcast days to hunt for millipedes.



Figure 6.3: Millipede: a potato pest observed during the experiment in Embo, February, 2005.

Some potatoes from the harvests had external symptoms of spherical swellings, pimple and warty-looking galls. Laboratory analyses identified *Meloidogyne* sp. (root-knot nematodes) in the tubers. Steyn (1997) noted that root knot nematodes were the most damaging nematode pest for potatoes in KwaZulu-Natal. Infected seed spreads nematodes (Evans and Trudgill, 1992; Steyn, 1997). Crop rotation using antagonistic

perennial plants such as blue buffalo grass (*Cenchrus ciliaris*), Katambora Rhodes grass (*Chloris gayana*) and weeping lovegrass (*Eragrostis curvula*) and ploughing in annual plants such as sun hemp (*Crotalaria juncea*), khakibos (*Tagetes* spp.) and *Brassica* spp may reduce the number of nematodes present in the soil and decrease crop damage below the economic threshold (Evans and Trudgill, 1992; Steyn, 1997).

Rotting losses were highest in summer (Table 6.2), the wet season in KwaZulu-Natal. The potatoes were diagnosed with bacterial soft rot (*Erwinia* spp.), fusarium dry rot (*Fusarium solani*) and common scab (*Streptomyces scabiei*). However, most of the rotting was due to soft rot. Soft rot bacteria are common soil inhabitants that are often dispersed through infected seed tubers and water (Hide and Lapwood, 1992; Toth, Bell, Holeva, and Birch, 2003; Urquhart, 1997). Soft rot causes more damage under wet, cool anaerobic conditions than under dry, aerobic conditions (Burton, 1989). Use of healthy seed, avoiding over irrigation and very wet production and harvesting conditions may help control this disease (Urquhart, 1997; Burton, 1989; Cedara Institute Plant Clinic, 2005; Hide and Lapwood, 1992). Generally, small scale organic farmers avoided harvesting potatoes in wet weather. However, the practice of using potatoes of unacceptable quality (including partially infected tubers) as seed perpetuates disease. Farmers could delay production in summer so that tuber development and maturation occur in conditions that are less conducive to rotting. Autumn and winter crops had fewer soft rot problems than the wet summer crop. Another important source of losses was potato greening.

Greening occurs when potatoes are exposed to light, due to the transformation of the amyloplasts to chloroplasts, accompanied by assembly of the photosynthetic apparatus in the potatoes (Edwards, 1997; Grunenfelder, Hiller, and Knowles, 2006; Machado, Toledo and Garcia, 2007). Greening potato tubers are considered unfit for human consumption because they contain high levels of the glycoalkaloids α -choconine and α -solanine that impart a bitter taste and are toxic to humans (Machado, Toledo and Garcia, 2007; Şengül, Keleş and Keleş, 2004). Consequently, greening potatoes are usually not selected by consumers and processors (Grunenfelder, Hiller, and Knowles, 2006). In this study, the farmer's store had the highest total per cent losses due to greening (Table 6.2).

Table 6.2: Percentage losses due to quality deterioration in organically grown landrace potato cultivar from three seasons left in situ, and stored in a farmer's store and in a controlled environment (7 °C and 90% RH) over two, four and six weeks

Season	Storage	Weeks of storage	Greening	Sprouting	Disease and pests	Total loss
Summer	<i>In situ</i>	2	1.22a**	0.00	30.06a	31.27a
	Farmer	2	0.78b	0.00	37.03b***	38.90a
	Controlled	2	0.78b	0.00	30.56a	32.16b***
		LSD _{0.05}	0.08	0.00	0.80	0.82
	<i>In situ</i>	4	1.77a***	0.25a***	29.81a	31.83a
	Farmer	4	3.68b***	0.00b	37.26b***	42.56b***
	Controlled	4	0.78c	0.00b	31.24a	33.34a
		LSD _{0.05}	0.12	0.01	0.79	0.70
	<i>In situ</i>	6	1.55a***	0.24	30.27a*	31.91a
	Farmer	6	3.68b***	0.66	38.26b**	45.95b***
	Controlled	6	0.78c	0.00	32.68c	35.14c*
		LSD _{0.05}	0.11	0.29	0.86	0.91
Autumn	<i>In situ</i>	2	0.07	0.00	4.38a	4.45a
	Farmer	2	0.00	0.00	12.23b**	13.78b**
	Controlled	2	0.11	0.00	4.33a	5.47a
		LSD _{0.05}	0.10	0.00	2.01	2.21
	<i>In situ</i>	4	0.05	0.00	5.31a	5.36a
	Farmer	4	0.00	0.00	13.67b***	17.14b***
	Controlled	4	0.11	0.00	4.33a	6.34a
		LSD _{0.05}	0.10	0.00	1.06	1.25
	<i>In situ</i>	6	0.06	0.00a	8.25a	8.31a
	Farmer	6	0.00	2.24b*	13.67b**	20.86b***
	Controlled	6	0.11	0.00a	4.33c*	6.89c*
		LSD _{0.05}	0.10	1.09	1.05	0.47
Winter	<i>In situ</i>	2	0.20	0.00	6.82a***	7.02a***
	Farmer	2	0.00	0.00	9.59b***	10.46b***
	Controlled	2	0.12	0.00	4.16c	5.41c
		LSD _{0.05}	0.13	0.00	0.21	0.13
	<i>In situ</i>	4	0.22	0.44a*	7.66a***	8.31a***
	Farmer	4	0.00	0.00b	9.59b***	11.17b***
	Controlled	4	0.12	0.00b	4.16c	6.14c
		LSD _{0.05}	0.20	0.30	0.21	0.80
	<i>In situ</i>	6	0.22	5.15a***	5.94a*	11.31a**
	Farmer	6	0.00	23.24b***	10.80b***	37.33b***
	Controlled	6	0.12	0.00c	4.16c	6.62c
		LSD _{0.05}	0.20	0.53	0.63	0.89

†Significant difference exists between two samples within the same season and length of storage followed by different letters at * p≤0.05 levels, **p≤0.01 and ***p≤0.00.

As stated earlier, potatoes in traditional storage were inadvertently exposed to indirect sunlight, which provided conditions conducive to potato greening. Table 6.3 shows a highly significant correlation between loss due to greening and growing season. Greening losses were higher in summer, probably due to higher temperatures and light intensity as opposed to the often overcast and cooler autumn and winter. Table 6.3 also shows that greening contributed significantly to total loss. Potatoes with green patches were consumed by the farmers (the greening sections were reportedly cut out because they made the potatoes bitter after cooking), used as seed or sold as seed to other farmers.

Table 6.3: Correlations between different forms of losses, season, method and length of storage, Embo and Pietermaritzburg, 2004-2005

	Season	Method of storage	Storage period	Total per cent weight loss	N
Total per cent weight loss	-0.74**	0.25	0.24	1.00	108
Per cent greening loss	-0.61**	0.19	0.20	0.73**	108
Per cent sprouting loss	0.24	0.23	0.30*	0.24	108
Per cent disease and pest loss	-0.85**	0.17	0.10	0.95**	108

Correlation is significant at the * $p < 0.05$ and ** $p < 0.01$ levels (2-tailed)

Sprouting also caused significant of loss, especially in winter, exceeding rotting losses in the farmer's store (Table 6.2). This may be due to the high starch content of the potatoes produced in this season (Katundu *et al*, 2007). The production conditions in winter are conducive to earlier tuber formation and starch accumulation in the tubers (Cutter, 1992). The early tuber formation means that the tubers were physiologically older at the time of harvesting and the high starch content provided readily available energy to support sprouting (Burton, 1989; Suttle, 2004). Sprouting potatoes were consumed by the farmers, used as seed or sold as seed to other farmers.

Desiccation resulted in higher losses in the farmer's store than in controlled storage (Table 6.4). The losses were only significantly higher at six weeks of storage.

Desiccation losses in the farmer's store may be attributed to lower environmental humidity levels. Although the potato skin helps to control desiccation, after the break of dormancy, there was increased water loss due to transpiration through the sprouts. This observation is similar to that made by Burton, van Es and Hartmans (1992).

Approximately 11% of potatoes produced in summer and autumn were too small for sale compared to 15.91% in winter. Similarly, summer had the highest proportion of larger potatoes (Table 6.5). Struik *et al* (1990) noted that tuber-size distribution is regulated by many diverse factors including plant density, number of stems per plant, number of tubers per stem, water availability and seed size.

Generally, summer and autumn were wetter than winter. As there was no irrigation, lack of water (especially during the tuber initiation and bulking periods) may have affected the potato tuber size distribution in winter. Over recycling of seed material and use of predominantly small potatoes, may have resulted in unintended selection for small size potatoes. Perpetual selection from own stock may have led to higher viral loads (Hane and Hamm, 1999). Although the viral loads of the potatoes was not investigated in the current study, in a study on effects of using virus infected seed tubers on yield of two potato cultivars, Hane and Hamm, (1999) found a 55.8 % and 79.4 % reduction in marketable yield.

Table 6.4: Potato weight loss due to desiccation of organically grown landrace potatoes when stored in a farmer's store and in a controlled storage over two, four and six weeks, Embo and Pietermaritzburg, 2004-2005

Weeks of storage	Method of storage	N	Per cent loss	Std. Err
2	Farmer's store	9	1.17	0.11
	Controlled storage	9	1.00	0.05
4	Farmer's store	9	2.22	0.32
	Controlled storage	9	1.69	0.09
6	Farmer's store	9	3.86a***	0.28
	Controlled storage	9	1.86b	0.12

Significant difference at *** $p < 0.001$ level exists between two samples within the same length of storage followed by different letters.

Table 6.5: Means of the proportion of smaller and bigger potatoes than baby potatoes sold by EFO farmers to the organic niche market expressed as a per cent age of total potatoes harvested in summer, autumn and winter, Embo, 2004-2005

Season	N	Per cent small potatoes		Per cent big potatoes	
		Mean	Std err	Mean	Std err
Summer	12	11.37a***	0.30	25.24a***	0.21
Autumn	12	10.54a***	0.10	10.29b***	0.11
Winter	12	15.91b	0.80	9.35c	0.08

Significant difference at *** $p < 0.001$ level exists between two samples within the same season and length of storage followed by different letters

6.4.4 Does loss of quality mean income loss?

Deterioration of potato quality constituted both partial and complete income loss for the small scale organic farmers. Rotten potatoes, especially where large portions of the tuber were rotten, constituted a complete income loss because the tubers were discarded. Since a large proportion of produce loss (especially in summer) was due to rotting and led to income losses. After six weeks of storage, the farmers store recorded the highest monetary loss from rotting at R133.91 per 100 kg of potatoes, reducing the average value of 100 kg of potatoes from R350.00 to R216.09 (Table 6.6).

Small, greening and sprouting potatoes were consumed by households, used as seed and sold as seed. Consumption of the produce meant that farmers saved on purchasing potatoes at market prices. Seed potatoes were sold at a price that was 14.29 % lower than the price offered by the pack house, resulting in income loss.

The highest loss due to small sized potatoes was R9.61 per 100 kg. Poor seed storage led to rotting which further reduced income from seed sales. However, potato seed storage and quantifying consequent losses was beyond the scope of this study.

Table 6.6: Monetary value of produce losses using the selling price of R3.50 offered by the pack house in the 2004/2005 season and R3.00 for seed potatoes

Season	Storage	Weeks of storage	Losses in Rands per 100 kg in storage due to:					Total loss R/100 Kg
			Greening	Sprouting	Pest and disease	desiccation [†]	small size [†]	
Summer	<i>In situ</i>	2	4.27	0.00	105.21	ND	6.28	115.76
	Farmer	2	2.73	0.00	129.61	3.82	5.68	141.83
	Controlled	2	2.73	0.00	106.96	2.87	5.68	118.24
	<i>In situ</i>	4	6.20	0.88	104.34	ND	4.92	116.33
	Farmer	4	12.88	0.00	130.41	5.67	5.68	154.64
	Controlled	4	2.73	0.00	109.34	4.62	5.68	122.37
	<i>In situ</i>	6	5.43	0.84	105.42	ND	5.68	117.37
	Farmer	6	12.88	2.31	133.91	11.73	5.68	166.51
	Controlled	6	2.73	0.00	114.38	5.88	5.68	128.67
Autumn	<i>In situ</i>	2	0.25	0.00	15.33	ND	5.33	20.91
	Farmer	2	0.00	0.00	42.81	5.43	5.27	53.50
	Controlled	2	0.39	0.00	15.16	3.61	5.27	24.42
	<i>In situ</i>	4	0.18	0.00	18.59	ND	5.24	24.00
	Farmer	4	0.00	0.00	47.85	12.15	5.27	65.26
	Controlled	4	0.39	0.00	15.16	6.65	5.27	27.46
	<i>In situ</i>	6	0.21	0.00	28.88	ND	5.37	34.46
	Farmer	6	0.00	7.84	47.85	17.33	5.27	78.28
	Controlled	6	0.39	0.00	15.16	8.58	5.27	29.39
Winter	<i>In situ</i>	2	0.70	0.00	23.87	ND	8.88	33.45
	Farmer	2	0.00	0.00	33.57	3.05	7.96	44.57
	Controlled	2	0.42	0.00	14.56	3.96	7.96	26.90
	<i>In situ</i>	4	0.77	1.51	26.81	ND	9.61	38.70
	Farmer	4	0.00	0.00	33.57	5.53	7.96	47.06
	Controlled	4	0.42	0.00	14.56	6.51	7.96	29.45
	<i>In situ</i>	6	0.77	18.03	20.79	ND	6.84	46.43
	Farmer	6	0.00	81.34	37.80	11.52	7.96	138.62
	Controlled	6	0.42	0.00	14.56	8.19	7.96	31.13

^{††} Desiccation losses were not quantified *in situ*, no values are therefore available.

[†] The value provided for farmer and controlled storage is an average of losses due to small size over the harvesting period in each season. The loss in this column is the difference in the value of the potatoes if sold as seed potatoes at R3.00 as opposed to R3.50 for table potatoes.

ND= not determined

6.4.5 Does sequential harvesting and storing potatoes help farmers get better prices for their potatoes?

The farmers produced primarily for a niche market, through the pack house. The pack house paid the farmers more for their produce compared to local market prices. The contractual arrangement between the farmers and the pack house fixed the potato price annually. In the absence of price elasticity, storage and delayed harvesting only served a preservation function. Delayed harvesting and selling did not result in higher income. There was no compensation for the losses incurred in storage or delayed income from the produce. Since the farmers supplied to the pack house in quotas on demand, they had limited choice over whether to sell all their produce at once or not.

6.5 Conclusion

The small scale farmers participating in the study experienced losses due to disease and pest damage, desiccation, sprouting and greening. Losses were highest in the farmer's store compared to controlled store and leaving the potatoes *in situ*. Except where the poor quality potatoes were consumed, quality loss due to small sized produce; diseases and pest damage; greening and sprouting resulted in reduced income. Reduction of losses can be achieved through good production practices such as planting healthy and bigger potatoes and effective pest and disease control. Crop rotation with plants that reduce pest infestation is recommended. Irrigation, especially in the drier months, would improve yields and increase the proportion of potatoes of sellable size.

Careful selection of potatoes to store and use as seed could exclude diseased potatoes, mitigate diseases in storage and ensure that the seed potatoes stay healthy. In order to maximise income from seed sales and reduce *Erwinia* infection, farmers need to avoid storage of seed potatoes in buckets that create anaerobic conditions conducive to the development of soft rot.

The farmers need to have a sustained source of healthy seed. Training the EFO farmers in organic production of seed potatoes of their traditional cultivar is essential. Flexibility on what cultivar to plant would be useful for the farmers if they are to take advantage of similar cultivars bred and selected for superior productivity and disease and pest resistance that are suitable for the farmers' farm environment.

The farmers produced potatoes on contract for a niche market. As the price for the produce was set annually by the pack house, there is need to ensure that storage costs are kept as low as possible owing to the absence of prospect of better prices to offset the cost of and losses in storage. Exploration of other niche markets offering similar or higher prices may give the farmers greater bargaining leverage for their produce. Alternatively, the farmers need to negotiate for market-related fluctuating prices. This will also ensure that the farmers, and not only the middleman and the retailer, benefit from seasonal fluctuations and general food price increases.

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CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Findings and conclusions

Improving small farm income is a powerful factor in reducing poverty and food insecurity. Increased consumer demand for healthy foods has encouraged supermarket chain stores to seek new and sustainable sources of organically grown foods. South African subsistence farmers, like those of the EFO who traditionally practice organic farming could be strategically positioned to benefit from this market demand. The demand provides an opportunity for small scale farmers to increase production and incomes since organic markets pay premium prices for produce.

Potatoes are an important cash crop for the EFO farmers. Preserving desirable potato quality to meet market expectations is a serious challenge due to lack of advanced storage facilities and insufficient knowledge of the effectiveness of alternative storage practices. Consumer quality expectations for organically grown potatoes and the effectiveness of traditional practices in maintaining those desirable potato quality characteristics had not been previously investigated. This investigation was essential to enlighten farmers on consumer expectation of their produce and optimise traditional storage practices.

Firstly, this study set out to investigate the effect of traditional farmer's store, *in situ* and controlled storage on the carbohydrate content and sensory quality of potatoes organically grown in Embo, by EFO farmers. Secondly, the study determined the consumer quality expectations of organically and conventionally grown potatoes. Thirdly, an investigation into the effect of sequential harvesting on the potato quality expectations of consumers was conducted. Finally this study investigated the produce and income losses experienced by small scale organic farmers at harvest and during storage.

A transdisciplinary approach to address the research problem was adopted. Research methods used included storage experiments with three of the farmers as co-researchers, sensory evaluations and producer and consumer surveys. The study is innovative in that adherence to farmer practices was ensured by the active

participation of three seasoned small scale organic farmers in the production, storage and quality evaluation of potatoes in storage and consumer defined quality attributes were used in assessing the effects of storage on potato quality.

This study pioneered research into the effects of sequential harvesting on potato quality and contributes to international knowledge on the effect of sequential harvesting on the carbohydrate content and sensory acceptability of potatoes. Secondly, the study contributes new knowledge on consumer appearance and keeping quality expectations of organically grown potatoes in South Africa. Finally this study contributes to knowledge on potato quality losses experienced by small scale organic farmers using traditional storage practices in South Africa and whether this results in revenue loss for the farmers.

A Comparative study on the effect of traditional farmer's store, *in situ* and controlled storage on the carbohydrate content and sensory quality of organically grown potatoes showed that *in situ* storage preserved desirable sensory qualities in potatoes. Potatoes left *in situ* had a low sugar and high starch content. Sensory evaluations showed that potatoes left *in situ* maintained a good texture and taste and were preferred to those from the farmer's store and controlled cold storage. An inconsistent relationship between carbohydrate content and sensory preference indicated that additional factors may have contributed to the sensory characteristics of the potatoes, particularly potatoes in traditional storage and in controlled storage. Glycoalkaloid content of the potatoes, which increases due to greening from exposure to sunlight and cold storage conditions, not investigated in this study, may have played a role in the sensory quality of the potatoes.

The investigation then looked at consumer quality expectations of organically and conventionally grown potatoes; the effect of farmer's store and sequential harvesting (methods currently used by the farmers in potato storage) on consumer expected quality of organic potatoes; and determined the effect of delayed harvesting on sensory and keeping quality of potatoes. The results have shown that organic consumers have similar appearance and keeping quality expectations of potatoes to conventional consumers. Five desirable potato appearance quality characteristics were highlighted: absence of greening, absence of sprouting, smooth skin texture, absence

of blemishes and light skin colour. Ninety-four per cent of the consumers interviewed expected potatoes to store for up to four weeks post purchase. A comparative analysis showed that the farmer's store reduced post harvest appearance quality compared to practicing sequential harvesting. In the farmer's store, quality losses increased significantly over the six weeks of storage mainly due to greening and sprouting.

Up to six weeks post maturity, leaving potatoes *in situ* did not deteriorate the sensory appeal of potatoes to consumers. Preference for potatoes harvested at maturity was not significantly different to potatoes harvested after six weeks *in situ*. Further investigation of the keeping quality of sequentially harvested potatoes with regard to dormancy breaking and sprouting showed that the later the potatoes were lifted, the shorter the dormant period post harvest. Seasonality affected the length of dormancy and hence keeping quality. However, sequentially harvested potatoes met post purchase shelf life expectations of consumer.

Potato quality losses were caused by disease and pest damage, desiccation, sprouting and greening. Small potatoes that could not be sold as table potatoes also constituted a loss for the farmers. Quality deterioration was highest in the farmer's store. Small sized tubers, diseases and pest damage, greening and sprouting resulted in reduced farmers' income from potatoes. Disease and pest losses caused quality and income losses. Losses were highest in summer due to *Erwinia* soft rot which thrives in wet soil conditions.

This study has demonstrated that sequential harvesting provides resource-poor small scale organic farmers with an efficient storage option where other storage methods and technologies may be inappropriate, ineffective or unaffordable. Sequentially harvested potato had superior carbohydrate content and sensory qualities.

Consumers considered absence of greening, absence of sprouting, smooth skin texture, absence of blemishes and light skin colour as indicators of good quality potatoes. They also expected potatoes to keep for at least three weeks post purchase. Sequentially harvested potatoes met these consumer quality expectations.

Potato quality deterioration resulted in revenue losses. The alternative uses for potatoes of unacceptable quality offered low economic benefits. Storing potatoes in farmer's stores increased produce losses. Pest and disease damage was a major problem. Use of low quality produce as seed stock seemed to increase disease and pest and parasites proliferation. Farmers therefore need to access disease and parasite free seed to ensure reduced losses and minimise spread of pests, parasites and diseases among the farmers.

Lack of water in drier seasons contributed to higher proportions of small potatoes that could not be sold as table potatoes. Excess water in summer increased diseases in tubers. Access to irrigation technology may present the farmers with an option to avoid potato production in these conditions. The technology would also offer the farmers an opportunity to control the amount of water supplied to the potatoes during production and mitigate diseases and optimise yield and potato quality.

7.2 Recommendations

It is recommended that, in the absence of other appropriate storage methods, farmers use sequential harvesting to preserve desirable potato quality characteristics. This is especially useful in relatively dry soil conditions. Farmers need to adopt production practices that reduce disease incidences like avoiding potato production in very wet conditions and using healthy seed stock. Seed potato production could provide additional income to the farmers. Seed production could also ensure availability of healthy seed for the farmers. Farmers need to be flexible enough to adopt new potato cultivars. Farmers could benefit from current technological advances that have seen development of potato cultivars with superior characteristics in terms of productivity, disease and pest resistance. Although this will introduce an expense due to seed procurement in the short run, in the long run, reduced losses and increased productivity would enable farmers to afford better quality seed and increase profitability of their farming. This is central to the sustainability of potato production as a livelihood for the farmers. Crop rotation with plants that reduce pest infestation is also recommended. The plants may include blue buffalo grass (*Cenchrus ciliaris*), Katambora Rhodes grass (*Chloris gayana*) and weeping lovegrass (*Eragrostis curvula*). Ploughing in annual plants such as sun hemp (*Crotalaria juncea*), khakibos

(*Tagetes* spp.) and *Brassica* spp may reduce the number of nematodes present in the soil and decrease crop damage below the economic threshold.

Farmers also need to explore diversification into production of essential oils like spearmint and peppermint. The oils would not only be a source of income but also provide locally produced organic potato sprout suppressant for the farmers. This would mitigate produce losses due to sprouting.

Farmers need to explore the possibility of irrigation farming which would facilitate control over the amount of water supplied to the potato plants to increase yields of marketable tubers in drier months but also help farmers control diseases like soft rot which thrive in excessively wet production conditions.

In light of the potential benefits of sequential harvesting, it is recommended that government and other players in the agricultural sector plan initiatives to educate small scale potato farmers on the benefits of sequential harvesting as an effective short-term method of potato storage. Government policy aimed at training and developing farmer capacity in organic seed potato production, especially of land race cultivars used by the farmers is essential. As indicated earlier, seed potato production may provide an additional market avenue for the farmers and ensure a sustained source of healthy seed potatoes as an essential part of disease and pest damage mitigation. Irrigation, especially in the drier months, would improve yields and increase the proportion of potatoes of sellable size. It is recommended that government policy with regard to small scale farmer support should focus on helping the farmers to access reliable water supply for production. Irrigation would provide farmers with options of when to produce, and consequently ability to avoid production in the excessively wet part of summer where losses due to rotting are high. Provision of irrigation opportunities should be coupled with farmer education on the water demands and critical water demand periods in the production of potatoes. Small scale farmers also need to be trained on ways of controlling the amount of water supplied to the plants to mitigate disease damage.

7.3 Recommendations for further studies

Potato cultivars may have different characteristics and the environment may affect the keeping quality of sequentially harvested potatoes. Consequently, research with other cultivars and in different agro-ecological settings is necessary to optimise the length of time farmers can successfully practice sequential harvesting. It would seem that this technique may also be used with other root crops like sweet potatoes and taro (*madumbe*). Further studies need to be undertaken to ascertain the effect of sequential harvesting on the keeping and sensory qualities of these crops.

Further research into the effect of size of seed potatoes on yields as well as potato virus loads is necessary. The research would ascertain if planting small sized potatoes has an impact on the potato yields among the farmers. Furthermore, it is recommended that future research should include analysis of glycoalkaloid content and textural characteristics of potatoes in the different storage methods, aspects which were not covered in this study.

APPENDIX 1 : QUESTIONNAIRE FOR PREFERENCE TEST-RANKING

Product: Sequentially harvested organically produced potatoes

Panelist number _____ 1 _____ Date:

Instructions

1. Please rinse your mouth with water before starting. You are also asked to rinse your mouth before testing the next sample. Please test the samples in the order provided from left to right. You can re taste a sample after you have tasted all the samples.
2. Rank the 3 samples from the most preferred to the least preferred using the following numbers. No two samples can be assigned the same number for preference i.e. no ties are allowed.

1= The most preferred 2 = preferred 3 = The least preferred

If you have any question please ask the server now.

Rank the samples you have tested in order of preference from 1 to 3

Sample Number	Rank (Ties are not allowed)
739	
844	
188	

What influenced your ranking the samples in this order (Please explain)

.....
.....
.....
.....
.....

Thank you very much for your participation.

APPENDIX 2: PANELLIST CONSENT FORM FOR PARTICIPATION IN THE SENSORY EVALUATION EXERCISE

TITLE: Effect of sequential harvesting and storage conditions on the quality of traditional organic potatoes produced by Ezemvelo Farmers Organisation

RESEARCHER: Mangani G.C. Katundu (260 6083 or 072 293 0052 email 204518771@ukzn.ac.za)

SUPERVISORS: Dr. Sheryl Hendriks
Prof. John Bower
Mr. Mthulisi Siwela

You are being asked to take part in a research study on sensory qualities of organic potatoes. Before agreeing to participate in this study, it is important that you read and understand the following explanation of the proposed study procedures. The following information describes the purpose and procedures associated with this study. It also describes your right to refuse to participate or withdraw from the study at any time. In order to decide whether you wish to participate in this research study, you should understand that what the study involves making informed decision. This is known as the informed consent process. Please ask the researcher to explain any words you don't understand before signing this consent form. Make sure all your questions have been answered to your satisfaction before signing this document.

Background

Small-scale organic farmers at Embo in Umbumbulu, a district in rural KwaZulu-Natal produce potatoes for an organic niche market. Due to labour, transport and marketing problems, the farmers practice staggered or sequential harvesting. Sequential harvesting is where a crop is harvested in phases after it has matured. Although the method has been reported to be successful elsewhere but on conventionally grown potatoes, in terms of low crop losses *in situ*, no work has been done on the effect of sequential harvesting on the quality (including sensory properties) of organically produced potatoes. Marketing quality produce ensures sustained access to niche markets and provide a route out of poverty for small-scale producers in rural areas. The aim of this study is to generate information on the effect of the practice on the quality of the potatoes and hence their profitable marketing.

Purpose

To investigate the effect of sequential harvesting and storage conditions on the sensory quality of traditional potatoes, organically produced by members of the Ezemvelo Farmers' Organisation.

Procedures

Potatoes of a traditional cultivar will be produced organically to maturity, approximately 14 weeks from planting. Sequential harvesting will be done from randomly designated plots, four times, at two-week intervals.

After harvesting, the potatoes will be manually sorted to remove all damaged, rotting, sprouted and greening potatoes. Some potatoes will be sampled at this stage for immediate sensory evaluation. The remaining potatoes will be divided into two categories on the basis of their weight and stored in either a controlled storage (7 °C and 90%RH) or farmers' storage

(ambient conditions). Sensory evaluation will be carried out fortnightly four times from the first harvest to the fourth harvest. Sensory tests to be used are descriptive test and preference test-ranking test. A minimum of 20 panelists will be used. The panelists will consist of students of the University of KwaZulu Natal, Pietermaritzburg Campus and will be recruited through a call for volunteers; this will be done verbally before lecture sessions and by use of posters. The prospective panelists will be trained and 20 will be selected for the sensory analysis.

Unpeeled potatoes from each harvest will be steamed for 45 minutes, cooled to the serving temperature of 60-65 oC, halved and presented to panelists in identical plates at the same time for each test. Panelists will use a fork to taste the potatoes.

Risks

In this study, the potatoes used are ordinary potatoes and care will be taken to ensure that only food grade potatoes are served for the evaluation. The preparation procedure is safe to ensure that the potatoes are safe to eat. You will be served with freshly cooked potatoes. Therefore the researcher anticipates no risks associated with this exercise.

Confidentiality

Throughout the study, you will only be identified by the number of the questionnaire you respond on. The numbering is meant to facilitate sorting out the results and will not be tied to your name. Therefore you will remain anonymous in the study results.

Participation

Your participation in this study is voluntary. You can choose not to participate or you may withdraw at any time without any consequences. However we request that you commit yourself throughout the entire period of the study.

Questions

If you have any questions about the study, please ask the researcher now or call Mangani Katundu on Extension 6083 or cell: 072 293 0052 or email 204518771@ukzn.ac.za

Consent

I have had the opportunity to discuss this study and my questions have been answered to my satisfaction. I consent to take part in the study with the understanding that I may withdraw at any time although the researcher would love if I were available for the entire study period. I have received a signed copy of this consent form. I voluntarily consent to participate in this study.

Participant's Name (Please Print) Signature Date

I confirm that I have explained the nature and purpose of the study to the subject named above. I have answered all questions.

Researcher Signature Date

APPENDIX 3: ETHICAL CLEARANCE NOTIFICATION FROM THE UNIVERSITY OF KWAZULU-NATAL FOR THE USE OF HUMAN SUBJECTS IN THE SENSORY EVALUATION OF POTATOES



RESEARCH OFFICE (GOVAN MBEKI CENTRE)
WESTVILLE CAMPUS
TELEPHONE NO.: 031 – 2603587
EMAIL : ximbap@ukzn.ac.za

27 JULY 2005

MR. MGC KATUNDU (204518771)
AGRICULTURAL SCIENCES


Dear Mr. Katundu

ETHICAL CLEARANCE NUMBER : HSS/05047A

I wish to confirm that ethical clearance has been granted for the following project:

“Effect of sequential harvesting and storage conditions on the quality of traditional organic potatoes produced by Ezemvelo Farmers Organisation”

Yours faithfully


.....
MS. PHUMELELE XIMBA
RESEARCH OFFICE

PS: The following general condition is applicable to all projects that have been granted ethical clearance:

THE RELEVANT AUTHORITIES SHOULD BE CONTACTED IN ORDER TO OBTAIN THE NECESSARY APPROVAL SHOULD THE RESEARCH INVOLVE UTILIZATION OF SPACE AND/OR FACILITIES AT OTHER INSTITUTIONS/ORGANISATIONS. WHERE QUESTIONNAIRES ARE USED IN THE PROJECT, THE RESEARCHER SHOULD ENSURE THAT THE QUESTIONNAIRE INCLUDES A SECTION AT THE END WHICH SHOULD BE COMPLETED BY THE PARTICIPANT (PRIOR TO THE COMPLETION OF THE QUESTIONNAIRE) INDICATING THAT HE/SHE WAS INFORMED OF THE NATURE AND PURPOSE OF THE PROJECT AND THAT THE INFORMATION GIVEN WILL BE KEPT CONFIDENTIAL.

cc. Faculty Officer
cc. Supervisor (Mr. M Siwela)

APPENDIX 4: PART OF THE EFO SURVEY QUESTIONNAIRE 2004

(Note : The complete survey questionnaire covered more than the section on potatoes)

CROP PRODUCTION SURVEY: EFO MEMBERS

Interviewer: Surname, Initial

Date: dd/mm/yyyy

Respondent is fully certified fullcert	1=yes 0=no
Respondent is not fully certified partcert	1=yes 0=no



The information captured in this questionnaire is strictly confidential and will be used for research purposes by staff and students at the University of KwaZulu-Natal to inform EFO farmers, prospective members and stakeholders how they might improve their organic farming venture. Respondents do not have to answer questions – answers are voluntary. The respondent must be a member of the EFO.

Respondent's full name		Household number:		GPS coordinate:	
Respondent's age					
Respondent's gender					

For further information call: Dr Sheryl Hendriks, Food Security Programme, University of KwaZulu-Natal. Tel: 033 2605726

1 **Crops produced organically** in the **2003/4** season (September 2003 – end of August 2004) (Note: some information about crops grown organically has already been gathered, and will be inserted before the interview)

Crops grown	Total area planted	Portion of total area planted that is rented in or borrowed (Specify unit e.g. 1/10 ha)	Sales to packhouse			Sales to non-organic markets ¹	
	(Specify unit e.g. 1/10 ha)		Sold to packhouse	Average unit price	Total revenue from sales	Average unit price	Total revenue from sales
			(Y or N)	(R/unit)	(Rands)	(R/unit)	(Rands)
Amadumbe							
Potatoes							
Sweet potatoes							
Green beans							
Fallow land							
Totals (for office use)							

Note: ¹ Sales to hawkers, local neighbours, Isipingo direct, etc.

2 **Crops produced inorganically** (i.e. with chemical fertilisers) in the **2003/4** season (September 2003 – end of August 2004)

Crops grown	Planted Y or N	Total area planted	Portion of total area planted that is rented in or borrowed	Average unit price	Total revenue from sales
		(Specify unit e.g. 1/10 ha)	(Specify unit e.g. 1/10 ha)	(R/unit)	(Rands)
Amadumbe					
Potatoes					
Sweet potatoes					
Dry beans					
Maize					
Sugarcane					
Bananas					
Chillies					
Other: Please specify					
Fallow land					

Totals (for office use)					
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3 If land was **borrowed or hired** to produce crops in the **2003/4** season (September 2003 – end of August 2004), capture the following information about the **main land transaction** (tick where relevant):

What type of transaction was negotiated? 0=n 1=y	<input type="checkbox"/> Cash rental cashrent <input type="checkbox"/> Crop payment croppay <input type="checkbox"/> No payment/Favour nopay <input type="checkbox"/> Return of a Favour Deleted
	<input type="checkbox"/> Verbal agreement verbal <input type="checkbox"/> Written contract written Deleted
	<input type="checkbox"/> Short-term (one year or less) shrterm <input type="checkbox"/> Long-term (more than one year) longterm
Who lent or rented out the land to you? 0=n 1=y	<input type="checkbox"/> Family relative loanfam <input type="checkbox"/> Friend loanfrnd <input type="checkbox"/> Stranger loanstrg Deleted

Was this main land transaction to borrow or hire land **specifically for organic crop production**? Yes No **0=n 1=y**

If yes, then for **which organic crop(s)**? _____

Inputs used for organic crops produced in the 2003/4 season (September 2003 – end of August 2004)

Input	Quantity used (kg)	Average unit price (R/kg)	Total cost (Rands)	Allocation of input between organic crops				
				Amadumbes	Potatoes	Sweet potatoes	Green beans	Dry beans
Purchased manure								
Own manure								
Own compost								
Purchased amadumbe seed								
Own amadumbe seed								
Purchased potato seed								
Own potato seed								
Purchased sweet potato seed								
Own sweet potato seed								
Purchased green bean seed								
Own green bean seed								
Hired labour								

Family labour									
Hired tractor and equipment									
Own tractor and equipment									
Hired draught oxen									
Own oxen									

4 **Potato keeping quality** in the **2003/4** season (September 2003 – end of August 2004) (tick where appropriate)

	Aug 03	Sept 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Mrch 04	Aprl 04	May 04	Jun 04	Jul 04
When do you plant potatoes? potpl...	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
When do you harvest potatoes? poth...	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

0=no 1=yes

6 **Potato harvesting, storage and grading** in the **2003/4** season (September 2003 – end of August 2004) (tick where appropriate)

What is the main factor that determines when you start harvesting potatoes? whenhar						
Do you practice sequential harvesting? seqhar	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	Why? Why not?				
Do you store potatoes for home consumption? potstore	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	How are potatoes stored?				
What is the main form of quality loss if potatoes are stored?		Sprouting sprout	Rotting rotting	Greening greening	Insect damage insect	shrinking: shrinking
Do you grade your own potatoes at harvest? grade	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	What qualities are used to grade potatoes? howgrade Size = 1 colour = 2 damage = 3				
Have you increased your area of potatoes over time? incrpot	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	Why? Why not?				
How many times did you sell potatoes to the packhouse last season? pktimes						
How many weeks do your potatoes remain saleable after harvesting? potweeks						
Is this a problem?	<input type="checkbox"/> Y1 <input type="checkbox"/> N0					

What qualities do you think consumers are looking for in organic potatoes?		
Do you think your potatoes meet the grade expectations of the packhouse? pkgrade	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	Why? Why not?
What quantity of potatoes grown last summer did you deliver to the packhouse? pkpotkg	(Kilograms)	
What quantity of your <u>own</u> delivery was rejected by the packhouse? plpotreg	(Kilograms or don't know)	
Could improved storage facilities or technologies lead to increased income from potatoes?	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	

7 Answer the following questions about **amadumbe** in the **2003/4** season (September 2003 – end of August 2004 (tick where appropriate):

What quantity of amadumbe grown last summer did you deliver to the packhouse? pkmadkg	(Kilograms)	kg
What quantity of your <u>own</u> delivery was rejected by the packhouse? pkmadreg	(Kilograms or don't know)	kg
Could storage facilities make you better off? storemad	<input type="checkbox"/> Y 1 <input type="checkbox"/> N 0	

Thank you for participating