Investigation of Selected Hygiene Parameters of uMbumbulu Small-scale Farmers' Organic Produce (leafy salad vegetables) and Subsequent Identification of Factors Affecting Farmer Practices and Food Security

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Abstract

The study aimed to investigate the hygiene quality of fresh agricultural produce, irrigation water and compost from four cooperatives (Jabulani, Nungwane, Senzakahle and Siyazenzela) supplying the uMbumbulu Agri-Hub Non-Governmental Organisation. In addition, the influence that socio-economic characteristics such as age, gender, level of education and training had on the uMbumbulu farmers' hygienic practices was investigated. Questionnaires, key informant interviews and laboratory analysis were used to collect data. The most probable number (MPN) method, a microbiological technique, was used to quantify selected hygiene indicators (i.e. total and faecal coliforms including *Escherichia coli*) from compost, irrigation water and leafy vegetables (spinach and lettuce) during the months of October, November and December 2011. Microbiological analysis on lettuce and spinach produced by the four Agri-Hub cooperatives confirmed that these vegetables were safe to eat and unlikely to cause sickness. The irrigation water sources, vegetables and compost faecal coliform levels met national standards with faecal coliforms of <1 000 MPN/100ml for irrigation and<200 MPN/g for the leafy salad vegetables. Compost faecal coliform levels were <1000/g and *E. coli* levels of <30 MPN/g, these levels decreased over the 3 months. Descriptive statistics such as the Chi-Square test using IBM SPSS and a logistic regression was performed using the STATA 11 software. The sample consisted of 60% female and 40% males, most of which (73%) were above the age of 40. A total of 60% of respondents received income from farming activities, receiving revenues of between R150- R250 a week. The logistic regression indicated that farmers already receiving some income from farming activities and those that had received training on hygienic farming practices were likely to wash hands and equipment prior to entering the field compared to those who had not. These variables influenced the hygienic practices with a probability of 26% and 32% respectively at 5% significance level. The logistic regression also showed that respondents with primary or no formal education were less likely to wash hands and equipment prior to entering the field compared to those who had a secondary level education. This unlikelihood had a probability of 35% for primary education and 43% for farmers with no formal education at significance levels of 5% and 10% respectively. This study indicates how training, education and farming experience are important and effective tools in implementing good hygienic practices in small-scale farming. The study's main

recommendations are that policies encourage farmer awareness on their responsibility of producing vegetables that are of good hygienic quality, especially if such produce is to reach the market. Furthermore policies should advocate for small-scale farmer training. This training should not be limited to subsistence farming but should also aim at preparing farmers towards accessing produce markets. Farmer training in hygienic practices should aid farmers to meet the stringent market standards allowing for better access, the regular income from such activities support farming as a livelihood and bearer of food security. It must also be noted that farmers require support in attaining the various resources needed in order to successfully and continually supply markets.

Declaration 1

I **F Mdluli** declare that:

- The research reported in this mini-dissertation, except where otherwise indicated, is my original research.
- This mini-dissertation has not been submitted for any degree or examination at any other university.
- This mini-dissertation does not contain other persons' data, picture, graphs or other information, unless specifically acknowledged as being sourced from those persons.
- This mini-dissertation does not contain other authors' writing, unless specifically acknowledged as being sourced from other authors. Where other written sources have been quoted then:
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- This mini-dissertation does not contain text, graphic or tables copied and pasted from the internet, unless specifically acknowledged, and the source being detailed in the mini-dissertation and in the references section.

Signed: ____

F Mdluli **Date**

As Research Supervisor, I agree to the submission of this mini-dissertation for examination.

Signed: ____

Dr JM Thamaga-Chitja **Date**

As Research co-supervisor, I agree to the submission of this mini-dissertation for examination.

Signed: ____

Prof S Schmidt **Date**

Declaration 2

Details of contribution to publication that form part and/or include research presented in this thesis.

Publication 1

Mdluli, F, Thamaga-Chitja, J & Schmidt, S. Investigation of the hygiene quality of water, compost and leafy vegetables produced by organic small-scale farmers in uMbumbulu, rural KwaZulu-Natal, South Africa: Implications for market access and capacity enhancement.

Author contribution:

Mdluli, F conceived paper with Thamaga-Chitja J and Schmidt S. Mdluli F collected and analysed data and wrote the paper. Chitja J and Schmidt S contributed with valuable comments to the manuscript.

Publication 2

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Author contributions:

Mdluli, F conceived paper with Thamaga-Chitja J and Shimelis, H. Mdluli F collected and analysed data and wrote the paper. Thamaga-Chitja J and Shimelis, H contributed with valuable comments to the manuscript.

Signed:____

F Mdluli **Date**

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Abbreviations and Acronyms

CFR	-Code of Federal Regulations (USA)
C-MAD	-Community Mobilization against Desertification
COD	-Chemical Oxygen Demand
DAFF	-Department of Agriculture, Forestry and Fisheries- South Africa
DOH	-Department of Health- South Africa
DWAF	-Department of Water and Forestry- South Africa
EC broth	-*Escherichia coli* broth
E. coli	-*Escherichia coli*
EFO	-Ezemvelo farmer's organisation
EMB agar	-Eosin-methylene blue agar
FCD act	-Foodstuffs, cosmetics and disinfectants Act, 1972 (Act 52 of 1972) RSA
GAP	-Good agricultural practice
GHP	-Good hygienic practice
GMP	-Good manufacturing practices
GTZ	-Deutsche Gesellschaftfür Technische Zusammenarbeit
HACCP	-Hazard analysis and critical control points
ICT	-Information and communications technology
ISO	-International organizations for Standardization
LST	- Lauryl Sulphate Tryptose broth
MDG	-Millennium development goals
MPN	-Most probable number

UNCTAD -United Nations Conference on Trade and Development

UNEP -United Nations Environment Programme

USEPA -United States Environmental Protection Agency

WHO -World Health Organization

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Chapter 1

Introduction

It is commonly acknowledged that sustainable agricultural methods need to be adopted in order to meet rising food demands (Wegner and Zwart, 2011). Organic small-scale farmers have the potential to play a crucial role in assisting to meet the rising food demands (Thamaga-Chitja and Hendriks, 2008). However, the farming practices of small-scale farmers are relatively unknown because small-scale farmers have not actively participated in formal food chains (Louw *et al*., 2007).

Small-scale farmers often have limited access to important farming resources (Thamaga-Chitja and Hendriks, 2008). Issues of water scarcity are relevant as agriculture consumes 73% of the global domestic water footprint (Hoekstra and Chapagain, 2007). This implies that alternatives regarding water resource development are becoming more and more restricted (Yokwe, 2007). Small-scale farmers who may have limited access to tap water may have no choice but to use natural sources of water such as river water of unknown microbial quality (Speelman *et al*., 2008). In fact, poor water quality has been identified as a major reason for the poor hygienic quality of fresh produce (DWAF, 1996).

Farming practices such as accessing good quality and uncontaminated seeds, the use and proper treatment of animal manure, knowledge of sources of contamination, personal hygiene and production hygiene are important as they influence the quality of the end product. These practices have recently come under the spotlight as fresh produce has been identified as a reputable vehicle for the transmission of pathogenic bacteria (EFSA, 2011; Deering *et al*., 2012). Outbreaks of sicknesses associated with pathogenic strains of *Escherichia coli* or other food pathogens such as *Salmonella* spp. have been reported all over the world (Nou and Luo, 2010). These outbreaks are partially due to the fact that these pathogenic strains of *E. coli* are able to attach to the surface of fruits and vegetables; in addition the bacterial cells might even enter the plant tissue (Deering *et al.,* 2012), thereby rendering rinsing with water ineffective. This is dangerous particularly for salad vegetables which are eaten raw and consequently fail to benefit from the heat generated during cooking (WHO, 2006). Furthermore, this poses a challenge to organic farmers who are prohibited from using chemicals in their farming practices and validates the importance of avoiding contamination at each farming step (Brackett, 1999; Burlace, 1995).

Recently, local retail supermarkets and other formal markets have attempted to make business with small-scale farmers as a part of their social responsibility and proudly South African drives (Louw *et al*., 2007). However, organic farming cooperatives, producing along principles not yet certified, have failed to take advantage of this opportunity because of complex quality standards that are often difficult and expensive to attain (Louw *et al*., 2007; Thamaga-Chitja and Hendriks, 2008). There are many barriers preventing farmers from accessing markets, one of these barriers is lack of knowledge on the laws, standards and recommendations they must satisfy prior to supplying large super market chains and other formal markets (Stefano *et al*., 2005; Thamaga-Chitja and Hendriks, 2008). The lack of access to markets affects small-scale farmers' food security negatively.

Research stresses the importance of farmer capacity building (Ko, 2010; Martins *et al*., 2012), where farmers are taught how to incorporate good farming practices into their farming routines (DAFF, 2011). Also, this is where farmers can be made aware of potential contaminants and how these can be prevented (Buck *et al*., 2003; Martins *et al*., 2012). Further, research suggests that the establishment of participatory initiatives which sees the involvement of government departments, established supermarkets, private entities, researchers and NGO's in small-scale farming may be beneficial (Louw *et al*., 2007; DAFF, 2011; Digbo and Momoh, 2007). On the other hand, it is necessary to determine what influences farmers practices so that these initiatives can be made relevant to the needs of farmers (Agwu and Edun, 2007).

Factors such as age, gender, level of education, geographic location, level of education and training play a role in the farming practices adopted by the farmer (Agwu and Edun, 2007; Martins *et al*., 2012; Serin *et al*., 2009). These factors differ vastly as different dynamics come into play, and these dynamics may be unique to certain communities. Determining the factors that influence farming practices is important as it provides a point of reference with regards to capacity building (Martins *et al*., 2012) as it identifies which groups require the most assistance and thus aligns interventions to particular target groups.

This study investigated the hygiene quality of fresh produce, irrigation water and compost using laboratory techniques. Furthermore, barriers and enablers influencing the market access of small-scale farmers were explored through the lens of hygienic practices employed by the farmers and how these may ultimately influence livelihoods and food security.

1.1 Characteristics of the study groups and area

This project solicited the involvement of the uMbumbulu community by working with the uMbumbulu Agri-Hub which focuses on all aspects of the organic farming value chain. The uMbumbulu Agri-Hub is an NGO implemented by the Newlands Mashu Community Development Foundation, supported by the eThekwini municipality and Project Preparation Trust of KZN (PPT). It is a pilot project which was launched in 2009 in close proximity to the small uMbumbulu town. It aims to provide comprehensive agricultural support to small scale farmers, encourage organic food production and aspires to produce high quality crops.

The main goal of the organization is to improve food security for all participants. The organization boasts over 40 trained small-scale farmers with new farmers joining the project regularly. Farmers involved in the project are trained in: Sustainable agriculture, soil management, water management, garden management, pest management, composting techniques and post-harvest protocols.

These small-scale farmers purchase seedlings and farming equipment at the Agri-Hub at discounted prices. The farmers then consume the organic products and sell their surpluses to the Agri-Hub at market prices per kilogram using a box scheme. The Agri-Hub supplies organic food markets and restaurants in Durban where the produce is sold under the "organically produced" label and not "certified organic" as the organization's produce is yet to be certified as organic. Plans to supply hotels with fresh organically produced vegetables are in the pipeline.

Farmers have grouped themselves into cooperatives that operate under the Agri-Hub. This also assists in peer supervision where cooperatives monitor each other to ensure that no chemicals are used in the vegetable production process. The cooperatives under study were: The Jabulani, Nungwane, Senzakahle and Siyazenzela cooperatives which were identified by key informants from the Agri-Hub as they all use different sources of irrigation (Tap, Dam, River and Spring water). Most farmers supplying the Agri-Hub use tap water, however, some irrigate using water from natural sources. Irrigating with water sources of unknown quality of water was a concern to the Agri-Hub as this was thought to influence the quality of the produce.

1.2 Importance of study

Historically rural small-scale farmers did not typically produce for markets. It is thus important that farmers are informed of their responsibility to produce food that is safe for consumption, especially if such food will reach the market. In order to access markets farmers need to satisfy a series of standards. This study investigated factors that influence farmer hygiene practices which inevitably determine the final quality of the produce. Furthermore, it assessed the hygiene quality of vegetables produced by small-scale farmers from uMbumbulu KwaZulu-Natal using microbiological analysis targeting selected hygiene indicators. This study intends to raise small-scale organic farmers' awareness of the different potential diseases their fresh produce can transfer thereby enabling them to take the necessary precautions with regards to their farming husbandry. Finally, it aims to identify socio-economic barriers and enablers which influence farmer practices which can be used as a basis for intervention programmes.

1.3 Research objectives

-Investigation of the types of vegetables and hygienic practices carried out by uMbumbulu farmers

-Quantification of the number of total and faecal coliforms as well as *E. coli* present on the surface of the vegetables

-Identify areas requiring capacity development in terms of food hygienic quality

-Identify socio-economic barriers and enablers influencing farming practices

1.4 Study limits

Presence of food borne pathogens such as *Salmonella* spp. or *Listeria monocytogenes* was not verified due to time and budgetary constraints

Limited time to carry out research therefore focus was placed only on two selected "high risk" leafy vegetables (Lettuce and spinach) and hygienic practices

1.5 Study assumptions

It was assumed that all respondents produced using organic farming principles and gave information that was true. It was further assumed that the months under study represent conditions and practices of the peak period where highest harvests and sales are observed.

1.6 Structure of mini-dissertation

The mini-dissertation is divided into five chapters. Chapter one introduces the topic, describes the group under study, the importance of the study, study limits and assumptions. The second chapter reviews literature on small-scale organic farming in Africa and South Africa. Furthermore, it identifies challenges, barriers and possible solutions hindering small-scale farmers entering the organic produce market. This chapter also reviews vegetables and other relevant substances as vehicles for the spread of pathogens. Chapter three presents draft journal paper conceived to investigate the quality of irrigation water, compost and subsequently leafy salad vegetables produced by uMbumbulu farmers. This paper further examines the implications of vegetable quality on market access and capacity building. Chapter four presents a draft journal papers investigating the influence of socio-economic characteristics such as age, gender, level of education and training on farmers hygienic practices. This chapter suggests a target audience for possible interventions. Finally, an overall summary, conclusions and recommendations are presented in chapter five.

Chapter 2

Literature Review

South Africa has an agricultural system that is dualistic (Aliber and Hart, 2009). Commercial and subsistence agriculture are at the opposite ends of the spectrum, while small-scale agriculture is indistinctly slotted in-between the two (Stats SA, 2012). The 1998 Eskom survey revealed that South Africa had over 2.1 million small-scale farmers and emerging farmers (Aliber and Hart, 2009). These small-scale farmers' contribution to agricultural output can be regarded as insignificant, with a contribution of less than 5% to South Africa's total agricultural output. However, small-scale farming is thought to have a good potential of contributing significantly to food security (Matshe, 2009; Stats SA, 2012).

Historically and traditionally, rural households have been known to successfully produce their own food (Stats SA, 2012; Twarog 2006). Rural black small-scale farmers in particular, have not farmed with a market orientation but rather for subsistence purposes. However, more recently studies such as the General Household Survey (GHS) of 2002-2011 conducted by statistics South Africa show that most South African households have become net consumers rather than net producers of food. So much so, that food expenditure accounts for as much as 80% of total household income for low-income households (Stats SA, 2012).

Households employ diverse livelihood strategies in an attempt to supplement and stabilize household food supplies (Matshe, 2009; Stats SA, 2012). These include social grants, remittances, agricultural activities and employment. According to the GHS survey rural South African households, unlike their sub-Saharan counterparts, are less likely to generate income through the small-scale production of food. Matshe (2009), accounts this to the failure of rural small-scale farmers to access markets and attain decent livelihoods from their farming activities.

Small-scale farmers' inability to market their surplus to niche markets is hindered not only by their inexperience and lack of knowledge but also the limited of access to productive land and reliable water resources (Thamaga-Chitja and Hendriks, 2008). In addition, small-scale farmers often have to compete for the market with well resourced farmers possessing more experience (Louw *et al*, 2007). These barriers contribute to the production of produce that may not meet the markets' stringent hygienic standards. This is due to the use of water resources of questionable microbiological quality, farmers being unaware of the importance of hygiene and uninformed on the points of entry of contaminants into the farming system.

Issues of microbiological quality in the rural small-scale farming sector of South Africa are even more critical to note given the policy drive to support and develop small-scale farmers in order to improve household food security and reduce poverty. This chapter collates relevant and critical literature on small-scale farming in Africa and South Africa. The literature is used to introduce the concept of organic farming as a means of attaining household food. Various barriers preventing access to markets are introduced, with particular interest on the hygienic quality of produce discussed. Possible points of entry of microbiological contaminant are discussed and South African regulations governing food safety highlighted. The microbial risk posed by the use of contaminated water and premature use of compost is discussed in detail wand dangerous pathogens highlighted. Recommendations to minimize the microbial contamination of vegetables are made with the capacity building of farmers seen as the most important tool to achieve this.

2.1 Defining a small-scale farmer

South African definitions of small-scale farming are often binary. According to Denison and Manona (2007), the South African agricultural sector is divided into two main categories: subsistence farming and commercial or business farming. Commercial farmers often have financial resources and a good ability to access markets. They also have larger farms which produce higher yields that are often accompanied by higher risks (Denison and Manona, 2007).

Small-scale or smallholder farmers often have diversified livelihood strategies. Small-scale farmers are often grouped as farmers who farm for household consumption, cash sale and even animal fodder. They participate in lower risk farming and frequently have a lower ability to access the farming markets because of their limited exposure (Denison and Manona, 2007).

2.2 The suitability of organic farming to small-scale farmers

Developing countries account for 98% of undernourished people, of which a large majority are found in Africa and Asia (Wegner and Zwart, 2011). According to Wegner and Zwart (2011), the world's population is forecast at 9.1 billion in 2050 requiring a 70% overall increase in food production. Small-scale farmers are often thought to have the potential of making a noticeable contribution in reducing these numbers and work towards fulfilling the first millennium development goal (MDG) of eradicating poverty and hunger (GTZ Sustainet, 2006; Hendriks *et al*., 2009).

Organic farming is an attractive option for poor small-scale farmers. This form of farming has been successful around the world, with small-scale farmers attaining economic and social benefits, all while preserving the environment (Pretty, 1995; UNEP-UNCTAD, 2008). Small-scale farming, when practised correctly, may positively contribute to food security, generate employment, has positive effects on the rural economy and contributes to reducing poverty (GTZ Sustainet, 2006; UNEP-UNCTAD, 2008; Wegner and Zwart, 2011). Furthermore, implementing small-scale organic farming may better ensure household food security and have greater potential in improving the quality of life of people (UNEP-UNCTAD, 2008).

2.3 Organic farming versus conventional agriculture

There is a raging debate about the differences between the quality and safety of organic versus that of conventional farming produce. Several investigations have proven that organic produce such as tomatoes and potatoes contain less nitrites and pesticides but more vitamin C and potassium when compared to conventional farming produce (Hallmann *et al*., 2010; Lairon, 2010). However, other investigations refute the perception that organic farming produce is of superior nutritional quality when compared to conventionally produced vegetables. Trewavas (2001), goes as far as stating that organic farming is an ideology that has no relevance in the world today as the world's problems require agricultural pragmatism and not ideology.

Although both conventional and organic farming have been reported to use manure as fertiliser, organic produce is considered to be a greater risk to public health (Gong, 2007; Oliveria *et al*., 2010). This is mainly due to the absence of physical and chemical treatments of manure in organic farming which when employed may reduce microbial load (Oliveria *et al*., 2010).

Conventional agriculture uses a variety of highly technological fossil-fuelled machinery to produce food in large quantities and at cheaper prices (Thompson, 2001). Conventional agriculture feeds most of the world (Connor, 2008), but is considered unsustainable because of its potential contribution to producing greenhouse gases. Although conventional agriculture is thought to disfavour ecological well-being (GTZ Sustainet, 2006), a number of strides have been made towards efforts to ensure soil and water quality protection.

Most people regard organic agriculture as synonymous with sustainable agriculture (Rigby and Cáceres, 2001). This is because organic farming is the most popular method of sustainable agriculture and is gentle on the environment (Rigby and Cáceres, 2001). The low input costs and added value of organic produce make organic agriculture more appealing to farmers. The questioning of organic farming's ability to feed the world (Connor, 2008) is irrelevant in this context, as organic farming is seen as more of a sustainable livelihood and less as a sole measure applied to correct and restore ecological harmony.

2.4 Small-scale organic farming in Africa

Small-scale organic farming has seen positive feedback particularly in Africa as organic farming principles are similar to those of traditional African farming and are therefore easier to implement and allow farmers to build onto their indigenous knowledge (Thamaga-Chitja and Hendriks, 2008; Twarog, 2006). The main similarity is the avoidance of using synthetic chemicals such as fertilizers and herbicides. This may not be entirely due to environmental considerations, but rather results from the costly price of chemicals and lack of usage knowledge (Barrow, 2006; GTZ Sustainet, 2006). However, it is important to note that under certain certification schemes, a limited use of pesticides is acceptable when no other means of pest control are effective (EU Council, 2007).

According to UNEP-UNCTAD (2008), organic farming has improved the quality of life for many African communities. Communities have not only witnessed better yields and income (GTZ Sustainet, 2006), but have also observed increased household food security, increased food access, nutritional security and stronger local social organizations (UNEP-UNCTAD, 2008). The Mount Kenya Organic Farm in Nanyuku, Kenya has reaped the benefits of organic farming (UNEP-UNCTAD, 2008). The Nanyuku community received over $ 64 000 in 2006 from selling organic seeds, as a result the community has better facilities and better assured food security (UNEP-UNCTAD, 2008).

The Muungano women's association in the Mkuranga district, Tanzania, practice organic farming with the overall aim of providing their children with a better education, healthcare, and good nutritious food through income generated from the sale of organic produce. Likewise, the C-MAD programme in Kenya has led to increased community food security, decreased child mortality and improved health and nutritious status (UNEP-UNCTAD, 2008). The Ezemvelo farmer's organisation was the first farming cooperative to be certified organic in South Africa (Thamaga-Chitja and Hendriks, 2008). It is a great example of how farmers, given sufficient support, can use organic farming as a sustainable livelihood that contributes to food security.

African governments have been investing and introducing mechanisms to improve capacity in organic farming (UNEP-UNCTAD, 2008). This has gone a long way in improving the food security of individuals and communities (GTZ Sustainet, 2006). However, initiatives that improve food security are tricky to implement due to the different forces and dynamics at play particularly in the African environment. African countries are often riddled by poverty, droughts, famines and bacterial outbreaks. Bacterial outbreaks have been previously triggered for example by *V. cholerae*, *Salmonella* spp., and pathogenic strains of *E. coli* (Zamxaka *et al*., 2004; Niehaus *et al*., 2011). The young, old, pregnant woman and immuno-compromised (YOPI) are often considered persons at high risk, as this group is thought to be most susceptible to bacterial infections (Gemmell and Schmidt, 2010). Unfortunately, outbreaks are often not reported due to the common culture of not notifying relevant authorities about these kinds of incidences or the source of the outbreak cannot be identified reliably (How we made it in Africa, 2011).

2.4.1 Small-scale organic farming in South Africa

According to Hendriks *et al*. (2009), one third of South Africans are involved in small-scale farming, even though it contributes less than 4% to their total income. Small-scale farming is often associated with non-productive and non-commercially viable agriculture. Ezemvelo farmer's organisation (EFO) is a certified organic farming group and is the oldest of its kind in South Africa (Thamaga-Chitja and Hendriks, 2008). It pools organic products grown by its members in a pack house where distribution takes place (Gadzikwa *et al*., 2006). This organisation has received support from the department of economic development and tourism, Woolworths, Pick n Pay and the department of agriculture and environmental affairs (Hendriks *et al*., 2009).

South African government and other stakeholders such as government, NGO's, research institutes and universities have established a few initiatives encouraging small-scale farming. The general goals and objectives of these initiatives is to provide possible means of livelihood and to obtain a certain level of household self sufficiency (Mthembu, 2009). Such programmes include the Agricultural starter pack programme, "One home, One garden" and "*Siyavuna" (*we are harvesting) projects (Hendriks *et al*., 2009; Ntuli, 2009).

The "One garden, One home" programme was launched by the Department of Agriculture, Environmental Affairs and Land Reform at iNkandla, KwaZulu-Natal in 2009 (Johnson, 2010; Mthembu, 2009). The government of KZN provided seeds to people to kick start home gardening. Initially this project was strictly a subsistence farming initiative. However, in certain parts of the province, the government partnered with the private sector and agricultural institutions, these partnerships worked hard to capacitate communities in sustainable organic farming encouraging small-scale farming (Johnson, 2010).

The relevant stakeholders continue to take great strides in implementing these programmes in a bid to alleviate food insecurity and create possible economic gains (Hendriks *et al*., 2009). A lot of barriers exist in the proper implementation and execution of these programmes with lack of knowledge being one of the main constraints. Communities interested in pursuing small-scale farming often do not know of the existence of institutions that can assist them when farming and have limited knowledge of the different farming techniques and agricultural standards. There have been a number of interventions aiming to overcome such constraints; however, interventions targeted at improving farmer knowledge on issues such as correct composting techniques, Integrated Pest Management (IPM) and the hygienic quality of vegetable produce have been limited.

Possessing skills that include composting and IPM would go a long way as South Africa has a growing number of organic farming consumers. The organic produce market is rapidly growing and is the second fastest growing division in the country's food sector (Barrow, 2006). There is a growing number of health conscious consumers shifting towards healthy living that believe that organic produce is a healthier alternative and a shift towards environmental preservation (Barrow, 2006). As a result, there appears to be a rapid growth in the organic farming sector. In 2006, there were 250 certified organic farms on 45 000 hectares of land (DAFF, 2011). The main South African organic producers include for example Kirklington Organic farm, Lorraine trust, Emerald Acres and the Modderfontein farm while the main South African processors include among others Allganix, Vital health foods and Blue Sky organics (Barrow, 2006). Pick n Pay, Spar, Woolworths and Checkers are South African supermarkets selling a range of organic products (Thamaga-Chitja and Hendriks, 2008).

Locally produced organic products are sold both locally and to international markets. According to Barrow (2006), South Africa organic farmers commonly produce lettuce, cabbage, broccoli, cauliflower and butternut among other salad vegetables. South Africa exports largely deciduous fruits, citrus fruits and avocadoes. According to Barrow (2006), organic fruit is typically exported before being sold to the local market, this is as a result of the high demand and price in Europe. In order to be able to supply international markets produce have to meet a series of steep international standards.

2.5 Challenges in small-scale organic farming

Small-scale farming is exposed to a number of challenges when compared to larger scale conventional farming. These include lack of access to capital, informal operations, vulnerability to price shocks, sub-standard quality (due to lack of training and skills) of produce and lack of relationships with the buyers in the market chain (Louw *et al*., 2007; Thamaga-Chitja and Hendriks, 2008; Wegner and Zwart, 2011).

Literature suggests that measures to improve farmer's capacity in increasing food production, quality, productivity as well as link to markets will result in their higher purchasing power (GTZ Sustainet, 2006; Thamaga-Chitja and Hendriks, 2008) and at the same time lead to increased food availability and food security. Interventions promoting small-scale sustainable agriculture are therefore challenged with providing intensive capacity building exercises (Digbo and Momoh, 2007; Martins *et al*., 2012).

One of the areas for capacity building is the improvement of the hygienic quality of organic produce where the possible points of contaminant entry are scrutinized and systematically dealt with (Brackett, 1999; Ko, 2010; Martins *et al*., 2012). Looking at the broader picture, small-scale farmers need to be informed on the possible ways of dealing with other issues associated with small-scale farming which include the daunting task of accessing markets and seeking support (Chitja *et al*., 2009; Louw *et al*., 2007).

2.6 Barriers preventing access to market

Small-scale farmers often face a number of challenges when attempting to access markets. Small-scale farmers are often inexperienced; they are unaware of strict market requirement, are unable to afford organic certification and are often unaware of niche markets. Given the policy drive to support and develop small-scale farmers in order to improve household food security and reduce poverty, finding solutions to these barriers is important in order for farmers to begin accessing fresh produce markets.

2.6.1 The market's (Woolworths) stringent hygiene requirements

South African small-scale farmers were largely sidelined in the past; as a result those entering the value chains for the first time are not well versed on the various quality safety standards (Louw *et al*., 2007). For example, farmers wishing to supply Woolworths must comply with GlobalGap standards (Louw *et al*., 2007). GlobalGap, formally known as EuroGap is world renowned for providing standards and guidelines for safe and sustainable agriculture. The guidelines according to GlobalGap, (2011) include:

-Ensuring that irrigation water contains < 1 000 faecal coliforms per100 ml

-Farm having documented hygiene instructions

-Record of training activities

-Potential hazards being clearly identified

The fulfilment of all GlobalGap criteria may be challenging as small-scale farmers often lack knowledge in production, control of pests, technical skills and soil nourishment (Chitja *et al*., 2009; Hashemi *et al.,* 2009; DAFF, 2011). Low literacy levels exacerbate the situation and as a result, the use of technologies which may be beneficial is not fully explored (Hashemi *et al*., 2009; Stefano *et al.,* 2005; Wegner and Zwart, 2011). Small-scale farmers also lack bargaining power and seldom influence agricultural policies (DAFF 2011; Wegner and Zwart, 2011). Low levels of education also contribute largely to the severity of foodborne diseases world-wide (Ko, 2010). The level of education goes hand in hand with the age of farmers in agriculture. According to Burton (2006), the age can suggest commitment to farming, experience in farming and the farmers farming philosophies. Older farmers are thought to have more information and are able to better answer farming questions. This is important as Agwu and Edun (2007) suggest that the higher the level of formal education of farmers, the lower the knowledge gaps and the higher potential of income from farming (Serin *et al*., 2009).

2.6.2 Inappropriate extension services

Farmers frequently require comprehensive extension services in organic production systems, the extension of inappropriate services often results in the lost chance of essential capacity building opportunities (Chitja *et al*., 2009; Thamaga-Chitja and Hendriks, 2008). Small-scale farmers in South Africa often have poor access to productive land with reliable water resources due historical segregation which led to land dispossession (Schreiner *et al*., 2004). In addition, the scarcity of alternatives such as the availability of credit for purchasing inputs further hinders the potential optimum production (Wegner and Zwart, 2011). This challenges role players to bring about innovative approaches in the introduction of capacity building exercises (Stefano *et al*., 2005).

2.6.3 Unaware of niche markets

Farmers are often unaware of niche markets in organic farming. According to Thamaga-Chitja and Hendriks (2008), farmers need to be made conscious of the array of vegetables they can farm in accordance to their climatic conditions. This is important because South African small-scale farmers tend to mostly cultivate only traditional crops such as *amadumbe* (taro) and *ubhatata* (sweet potato). Furthermore, small-scale farmers may sometimes face competition as they often have to compete with more experienced, well informed and established farmers when looking to supply companies that have very high quality and food safety standards (Louw *et al*., 2007; Wegner and Zwart, 2011).

2.6.4 Organic certification in South Africa

Organic certification is the conformation by a certification agency that products are indeed produced organically and not using conventional methods (Barrow, 2006; DAFF, 2011; Thamaga-Chitja and Hendriks, 2008). Currently, South Africa has no regulations that compel organic producers to be certified (Barrow, 2006; DAFF, 2011; Thamaga-Chitja and Hendriks, 2008). For this reason the organic standards are at the discretion of the retailers. Woolworths for instance, requires their suppliers to be certified as organic by ISO accredited agencies using the GlobalGap standards Framework (Barrow, 2006; Louw *et al*., 2007).

In addition, South Africa does not have a single body that represents the organic farming sector (DAFF, 2011). Furthermore, it lacks official inspection and certification programmes and this task is often performed by private companies (Barrow, 2006). As a result farmers pay exorbitant prices for certification (DAFF, 2011; Thamaga-Chitja and Hendriks, 2008).

The certification of small-scale farmers is important in upholding the organic produce sector. Unfortunately, high certification costs hinder small scale farmers from organic certification (Thamaga-Chitja and Hendriks, 2008). The formulation of South African organic standards would lower certification costs and would facilitate information flow and trust between farmers and government (Thamaga-Chitja and Hendriks, 2008).

2.7 Overcoming barriers

A realistic approach in achieving increased food production while decreasing environmental effects requires supporting and empowering subsistence and small-scale farmers to be able to better cope with risks (GTZ Sustainet, 2006). Research indicates that the greatest financial returns and food security is achieved when women farmers are supported. Therefore programmes that particularly target women small-scale farmers are important (Agwu and Edun, 2007; Wegner and Zwart, 2011). Women produce, process and prepare food and are largely involved in farming programmes (Modi, 2003). Women have also been reported to posses greater farming knowledge than men (Agwu and Edun, 2007). Unfortunately as a result of stereotypes women's roles in farming have largely been restricted to production roles (Trauger *et al*., 2008). A large number of these stereotypes suggest that women are not physically capable of partake in farming activities such as the driving of tractors.

Soliciting the involvement of both male and female farmers is imperative in the development of domestic markets. This can be achieved by active government participation where interventions encouraging regional trade, supporting farmer organizations and the implementation of more stringent import regulations (DAFF, 2011: Wegner and Zwart, 2011). Having national institutes representing organic farming is important (DAFF, 2011; Thamaga-Chitja and Hendriks, 2008) as such bodies may create and enforce important regulations.

Small-scale farmers require training in various aspects of the farming process (Digbo and Momoh, 2007). This training should focus on issues pertaining to potential microbiological contamination in the farming environment because fresh produce is known as vector spreading disease. Farmers need to be well educated in the storage of seed prior to planting and the storage of produce following harvest. Furthermore, they need to recognise the business prospects of farming. One way of achieving this may be to build relationships between large- and small-scale farmers; this setup would give small-scale farmers an opportunity to assist larger scale farmers to meet their demands (Louw *et al*., 2007; Wegner and Zwart, 2011). This requires generous financial support which will aid in attracting trading partners increasing productivity (UNEP-UNCTAD, 2008).

2.8 The role of fresh produce in the spread of disease

The consumption of raw and minimally processed fruit and vegetables is an increasing trend as consumers become more aware of the benefits of healthy eating (Barrow, 2006; Buck *et al*., 2003). Ready-to-eat vegetables not requiring cooking prior to consumption are increasingly being recognized as key vehicles of the transmission of food borne illness (Little and Gillespie, 2008; Nou and Luo, 2010). This is largely due to the fact that they fail to benefit from the heating of food, as proper cooking can achieve an almost quantitative reduction of pathogens by up to 5-6 log units (WHO, 2006).

Acknowledging the potential link between fresh produce and disease outbreaks is imperative (Beuchat, 1996),especially as fresh produce is frequently identified as being a culprit in many outbreaks (Buck *et al*., 2003; Frank *et al*., 2011). The role of fresh produce in disease transmission has been documented (Brackett, 1999); gastroenteritis, traveller's diarrhoea and salmonellosis have been closely linked to fresh produce contamination (Buck *et al*., 2003). Recently, Germany and France saw the deaths of 47 people as a result of contaminated sprouts. The German EHEC Task Force[1] later traced the contamination to contaminated fenugreek seeds imported from Egypt (EFSA, 2011). This case not only shows the role of fresh produce in the disease outbreak chain, but also that seeds are prone to bacterial contamination.

[1] The German Enterohemorrhagic Escherichia Coli Task Force

2.8.1 Importance of the hygienic quality of salad vegetables

One important type of training small-scale farmers can receive is that which assists in ensuring the hygienic quality and safety of vegetables. The number of outbreaks associated with the consumption of raw fruit and vegetables continues to increase in recent years (Buck *et al*., 2003; Frank *et al*., 2011). Although different microorganisms have been associated with produce linked outbreaks, most are considered to be of bacterial origin (Brackett, 1999; Cliver, 1987; Gong, 2007).

Pathogenic strains of *E. coli* such as STEC or EHEC, *B. cereus, Salmonella* spp., *Shigella* spp. and *S. aureus* are examples of bacterial pathogens which have been associated with outbreaks due to fresh and frozen produce outbreaks (Beuchat, 1997; Garcia-Villanova Ruiz *et al*., 1987; National Advisory Committee on Microbiological Criteria for Foods, 1999). *E. coli* outbreaks were reported in Japan in 1996, USA in 2006 and more recently in Europe as a result of contaminated seeds and sprouts (Berger *et al*., 2010; Frank *et al*., 2011). Gastroenteritis, also known as stomach flu, is the inflammation of the gastrointestinal track and can be caused by pathogenic strains of *E. coli* (Buck *et al*., 2003). Such strains of *E. coli*, as well as *Campylobacter* spp. and *Salmonella* spp. are usually responsible for traveller's diarrhoea. *Salmonellosis,* the infection of the lining of the intestinal tract is caused by *Salmonella* species (Buck *et al*., 2003) while *B. cereus* (food toxin producer)has been documented to cause gastrointestinal illnesses (Beuchat, 1996).

Microbial safety is particularly important in organic farming practices. A number of foodborne diseases have been linked to organic farms (Buck *et al*., 2003; Frank *et al*., 2011). Standard organic practices such as composting, irrigation and the absence of pesticides and bactericides whilst using manure instead of chemical fertilizers may theoretically and practically increase the risk of microbial contamination. In this instance it is important that good hygienic practices (GHP's) and quality regulations are followed.

2.8.2 Sources of bacterial contamination at different stages of small-scale production

Everything in the farming environment that is in contact with the plant has the potential to be a source of contamination (Brackett, 1999) and all the different stages of farming introduce factors which may influence the hygienic quality of the final product. Hence, the areas of handling pre-

(seed handling, fertilization and irrigation) and post-harvest, processing, packaging and distribution should receive attention in a bid to curb microbial contamination (Beuchat, 1996).

The identification of the source of microbial contamination is important to minimise future outbreaks. During pre-harvest one possible source of contamination is the soil. For example, an area where livestock previously grazed is likely to be contaminated with enteric pathogens (Brackett, 1999). Other sources of contamination is the incorrect storage of seeds (contamination by rodents etc.), insects and snails that can spread pathogenic bacteria as they move from plant to plant (Berger *et al*., 2010). Manure that has not been properly composted may also be dangerous (Berger *et al*., 2010; Buck *et al*., 2003). However, one of the most important causes of contamination identified in the literature (Buck *et al*., 2003) is the use of microbial polluted irrigation water. It is therefore important to know the history, distribution and origin of the water source. Also the mechanism used for irrigation (drip, bucket or sprinkler irrigation) is important. Overhead sprinklers result in droplets of water on the surface of the fruit and leaves of the produce. Should the water be microbiologically contaminated, bacterial internalization can take place thus rendering thorough rinsing post harvest ineffective (Berger *et al*., 2010). It is very difficult to remove pathogens such as *E. coli* and *Salmonella* spp. once they have attached themselves to the surface of the produce and have formed biofilms (Berger *et al*., 2010). It is for these reasons that experts encourage drip irrigation although this irrigation may not be a cost effective option for small scale farmers. Farmers may instead employ bucket irrigation, but take care to water at the root of their produce. It is also important that all farm workers practice good personal hygiene as most foodborne pathogens are transmitted by humans (Brackett, 1999; Ko, 2010; Martins *et al*., 2012). Ensuring that post-harvest equipment, containers and processing equipment are all sanitised is important in reducing post harvest contamination (Brackett, 1999; Buck *et al*., 2003).

2.9 Laws governing food safety in South Africa

Food manufactured, processed and sold in South Africa and all imported foodstuff are governed by the FDC act of 1972, which aims to control the sale, manufacture and importation of foodstuff, cosmetics and disinfectants and to address incidental matters[2]. There are two

[2]The foodstuffs, cosmetics and disinfectants (FCD) Act 54, 1972. This act has two sets regulations dictating the microbial safety standards for foodstuff. These regulations are R.692 of 16 May 1997 and R.1555 of 21 November 1997 (DOH, 2002).

regulations under this act that govern microbiological standards for foodstuffs and related matters (R.692 of 16 May 1997).

According to DOH (2002), this regulation (R.692 under FCD act) stipulates the microbiological standards for commodities such as: desiccated coconuts, sugars for canning, edible gelatine, seafood, poultry, bottled water, spices and dried aromatic plants (herbs and egg products). The other regulation under the FCD act, R.1555 of 21 November 1997 is specific to milk and milk products.

Unfortunately regulations for raw fruit and vegetables are not sufficiently covered by the current legislation. In such a case the rule of thumb is that foodstuff should ideally not contain any microorganisms (DOH, 2002). Should it contain microorganisms which is normally the case, their levels should be such that they cause no harm to humans upon consumption. There are however recommended guidelines for raw fruits and vegetables (Table 2.1), including fresh fruit salad, salad dressing and peanut butter.

Table 2.1: Recommended limits for bacterial food hygiene indicators and pathogens as well as yeasts and moulds for raw fruit and vegetables (ready to eat) in accordance to the South African, EU and DGHM

Microorganism	South African (Bacteria numbers/ g)	European Union (m/M)	DGHM (m/M)
Total coliforms	<200/g	-	-
Salmonella spp.	0/25g	0/25g	0/25g
E. coli	0/g	100/1000 cfu/g	100/1000 cfu/g
Yeast and mould count	<100 000/g	-	<10 000/g (Yeasts only)

(DOH, 2002; European Commission, 2007; DGHM e.V. 2012)

2.9.1 Water quality standards and decreasing incidences of vegetable contamination

Chapter 5 of the water quality guidelines (DWAF, 1996) stipulates the effect of faecal coliforms on crop quality. The WHO guidelines for grey water and excreta suggests that faecal coliforms should not exceed 1000/100ml (WHO, 2006). Suggestions to decrease possible transfer of human and animal contamination are identified, these include:

- Only irrigating crops that will be cooked prior to consumption with questionable water sources if this cannot be avoided
- Allowing sufficiently long intervals between the last irrigation and harvesting to allow for the natural die-off of pathogens. Studies in Ghana suggest at least a 4-5 day interval after irrigation with waste water even though this may result in the reduction of the fresh weight of the vegetable (Qadir *et al.,* 2010). Also, according to Keraita *et al*. (2007), this method is most beneficial during the dry seasons as the wet seasons result in splatters that may result in recontamination.
- The use of drip irrigation, a method that avoids wetting the leaves especially when irrigating leafy vegetables.
- The cooking of vegetables at high temperatures before ingestion is the most effective way of reducing the numbers of pathogens in and on vegetables. Otherwise, thoroughly washing vegetables with clean water is important (Qadir *et al*., 2010) albeit not reliable as internalization of pathogens is known to occur (Deering *et al*., 2010).
- Also peeling outer leaves or covering of vegetables is important as the majority of microbiological contamination is exogenic (Qadir *et al*., 2010) given that no internalization took place.

Water scarcity's contribution to poor water quality

Water scarcity is a phenomenon where water demand exceeds its availability (Enright, 2000). This demand often comes from agriculture, household and general demand due to economic and population growth (Vairavamoorthy *et al*., 2008). The increase in water demand means that the share currently used by the irrigated agriculture sector will be reduced and water use will become more expensive (Speelman *et al*., 2008). Currently, agricultural production accounts for 73% of the global domestic water footprint with industrial and domestic consumption using up 6% and 5% respectively (Hoekstra and Chapagain, 2007). The remaining 16% is accounted for by the water footprint used in the production of imported goods (Hoekstra and Chapagain, 2007). The degradation of water quality increases water scarcity as it may not conform to current water standards legislation.

Water scarcity has negative consequences particularly for poor small-scale and subsistence farmers. The costly nature of tap water makes natural sources of water such as rain, dam and river water of unknown microbial quality the only alternative (Speelman *et al*., 2008).There are expensive agricultural implications if these natural sources contain water of inferior quality. However the fact that small-scale farmers often use these sources of water for irrigation cannot be ignored (Obi *et al*., 2002; Zamxaka *et al*., 2004).

Potential links between water quality and microbial quality of produce

Poor water quality is thought to be a major reason for the lack of microbial safety of the final vegetable product (DWAF, 1996). In fact, a study carried out in Pietermaritzburg, South Africa (Gemmell and Schmidt, 2010; Gemmell and Schmidt, 2012) demonstrated the possibility of microbial transfer from contaminated irrigation water to fresh produce. This study, conducted in KwaZulu-Natal, explored possible links between the quality of irrigation water and microbiological quality of vegetables (Gemmell and Schmidt, 2010). Laboratory analysis revealed that the total number of faecal coliforms exceeded the WHO (2006) recommendation for safe use of irrigation water. Furthermore, microbiological analysis demonstrated the presences of potential pathogens such as *Salmonella* spp. (Gemmell and Schmidt, 2012a,b).

Studies conducted in the rural communities of the Eastern Cape and Limpopo provinces demonstrated similar results (Obi *et al*., 2002; Zamxaka *et al*., 2004). The faecal coliform counts of untreated water sources were higher than the maximum acceptable limits (Obi *et al*., 2002). According to Zamxaka *et al*. (2004), these counts can be attributed to poor hygiene, lack of sanitation and general lack of awareness of people on issues that included the hazards of sewer overflow.

2.10 Compost in organic farming

Compost is a material commonly used in organic farming to fertilise and replenish the soil (Gong, 2007). Compost is a dark brown/ black soil like material with an earthy odour. It is the final product of organic materials resulting from the aerobic decomposition action of microorganisms and may be a source of contamination in the farming environment (Baldwin and Greenfield, 2009). Compost benefits the soil in various ways; it enhances soil fertility, increases the biological activity of the soil and improves physical structure (Favoino and Hogg, 2008). It helps to regenerate poor soils and remediate contaminated soil (Borken *et al*., 2002). Compost also encourages the growth of earthworms and increases the soils ability to retain water and nutrients (Cogger, 2005).

2.10.1 Science of composting

The organic substrates for composting are normally derived from plant materials where reduced carbon (C) compounds act as a source of energy for microbial growth (Ryckeboer *et al*., 2003; Wong *et al*., 1999). The final product may take up to 6 months to mature, however the rate of composting may be increased considerably by breaking or grinding organic matter into smaller fragments thus increasing the surface area (Baldwin and Greenfield, 2009). Moreover, the duration of the different composting phases depends on the initial organic matter, pH, temperature, oxygen (O_2) and moisture (Ryckeboer *et al*., 2003).

There are distinct differences between composting and natural decomposition. The main difference is human intervention which accelerates the process (Baldwin and Greenfield, 2009). When composting, different materials are placed layer by layer until a heap like structure is achieved. These layers may comprise of: tree branches, green leaves, dry grass, animal manure, vegetable peels and sometimes firewood ash. Oxygen, temperature and moisture are very important parameters governing the decomposition process (Baldwin and Greenfield, 2009). The oxygen is usually administered into the system by making a pole sized incision in the middle of the heap, and moisture by light watering of the heap. The oxygen and moisture are compulsory for the survival of aerobic bacteria and fungi (especially moulds such as *Aspergillus* spp.) as these microorganisms thrive in oxygen rich environments and decomposition principally occurs via microbial biofilms established on the surface of the organic substrates (Baldwin and Greenfield, 2009; Ryckeboer *et al*., 2003).

2.10.2 Composting phases

The composting process can be divided into four stages under optimal conditions. Mesophilic phase (i), thermophilic phase (ii), second mesophilic phase (iii) and maturation and stabilizing phase (iv) (Ryckeboer *et al*., 2003). These stages are facilitated by the overlapping of temperature ranges (Baldwin and Greenfield, 2009). Temperatures of the compost heap includepsychrophilic (-5 – 15°C), mesophilic (10-40°C) and thermorphilic temperatures (35-70°C) which accommodate different microbial communities (Ryckeboer *et al*., 2003).

Phase I

Mesophilic Phase

While psychrophiles are somewhat involved in the decomposition process, the decomposition is carried out mainly by mesophilic bacteria and fungi. These microorganisms ‘activate” the compost as they start breaking down readily degradable polymeric compounds like sugar, starch, protein and fats in hydrolytic reactions (Baldwin and Greenfield, 2009). The microflora involved in this initial phase is inhibited by high temperatures which may stimulate the growth of thermophiles (Ryckeboer *et al*., 2003); at these high temperatures mesophiles may form endospores.

Phase II

Thermophilic Phase

Mesophiles create physico-chemical conditions which promote the growth of thermophilic bacteria and some thermophilic fungal species such as *Aspergillus fumigates* which are secondary decomposers (Ryckeboer *et al*., 2003). These microorganisms continue with degradation but at more rapid rates (Baldwin and Greenfield, 2009). Mesophilic pathogens (disease causing) are typically destroyed as temperature rise above 55°C, while weed seeds and insect larvae are destroyed when temperatures reach 63°C.

Phase III and IV

After the organic matter has been decomposed, the temperature of the heap declines steadily (Baldwin and Greenfield, 2009). The size of the heap also becomes more compact. Phase iii, the second mesophilic phase proceeds until nutrients become limiting factors which results in a decline of microbiological activity (Ryckeboer *et al*., 2003). The final phase (maturation phase)occurs when complexes such as lignin-humus are formed which are not further degradable (Ryckeboer *et al*., 2003).

In addition to the C source, microorganisms also require nitrogen (N), phosphorous (P), sulphur (S) and potassium (K) (Ryckeboer *et al*., 2003; Wong *et al*., 1999). Nitrogen, is a particularly important element for the growth of microorganisms (Ryckeboer *et al*., 2003). However, when in excess it is lost through the process of volatilization where nitrogen is released in the form of ammonia(or, under oxygen limiting conditions via denitrification in the form of N_2O or N_2) especially under alkaline conditions (Baldwin and Greenfield, 2009). If limited, nitrogen may slow down the rate of degradation (Ryckeboer *et al*., 2003).

2.10.3 Compost standards

Countries around the world are attempting to publish compost guidelines (Table 2.2). European countries are ahead with designing compost guidelines while the rest of the world follows (Brinton, 2000). Differences in scientific opinions create areas of ambiguity, for example scientists fail to come to a common definition of the "critical level" of substances in compost. According to the United Stated Environmental Protection Agency's (USEPA) Code of Federal Regulations (CFR), biosolid based composts should have faecal coliforms at levels of < 1 000/g and for *S.typhi* <3/g before its application (US EPA, 1993). Composts that meet these criteria are referred to as Class I composts.

Table 2.2: Example of countries making progress with designing compost guidelines and practices to ensure reduction of pathogens

Country	Guideline status	Pathogen reduction method
Austria	Fully established quality assurance system	Compost has to reach 60°C for a minimum of 6 days or 65°C for at least 3 days
Australia	Established quality criteria and methods of analysis	Compost has to reach 55°C for at least 3 days
Germany	Fully established quality assurance system	Compost has to reach 55°C for a minimum of 2 weeks or 65°C for 1 week

Adapted from (Brinton, 2000)

2.11 Manure in organic farming

The use of animal manure is common in organic farming practices (Gong, 2007). However, manure, a compost ingredient, is also known for containing an array of pathogenic microorganisms (Buck *et al*., 2003; Joy *et al*., 1998). Organic farming practices therefore theoretically increase the chances of the microbial contamination of fresh produce (Gong, 2007). Due to lack of knowledge, small-scale farmers often apply kraal manure directly into the soil (van Averbeke and Yogananth, 2003). It thus is important that small-scale farmers understand the potential hazards of using compost so they can limit and prevent possible contamination.

Cow manure is a popular compost ingredient as it is very economical for farmers that own cattle and usually freely available to those who do not. However, studies have shown that manure has the potential to be a source of microbial contamination (Joy *et al*., 1998). The absence of pesticides and bactericides and the extensive use of manure make organic agriculture theoretically more prone to microbial contamination (Unc and Goss, 2004). According to Unc and Goss (2004), the occurrence of faecal bacterial contamination was higher for farms using manure than those utilizing mineral fertiliser. The most common bacteria found included faecal coliforms, *Streptococcus* spp and *Salmonella* spp. (Table 2.3) (Unc and Goss, 2004).

Pathogens such as *E.coli* O157:H7 have been reported to survive longer in manure rather than soil (Wang *et al*., 2004). On the other hand coliforms have been known to survive for periods greater than 3 months in soil/manure (Wang *et al*., 2004). Proper management of animal manure than becomes key as it known to contaminate ground and surface water (Unc and Goss, 2004; Wang *et al*., 2004).

Table 2.3: Selected literature data on faecal coliforms, *Salmonella* spp., faecal streptococci, as well as *E. coli* in livestock manure

Manure type	Faecal coliforms cfu/g	*Salmonella* spp. cfu/g	Faecal streptococci	Source
Dairy Cow (fresh manure)	1.20×10^7 to 1.65×10^7 (d. wt.)	-	9.52×10^4 to 9.31×10^6 (d. wt.)	(Wang *et al*., 2004)
	6.55×10^6 to 7.60×10^6 (*E. coli*; d. wt.)	-		
	1.00×10^3 to 1×10^5 (*E. coli* O157:H7) (f. wt)	-		(Zhao *et al*., 1995)
Cow (fresh manure)	-	>1.00×10^6 (d. wt)	-	(Mawdsley *et al*., 1995)
		<1.00×10^2 to 1.00×10^7 (d. wt)		(Pell, 1997)
Sheep	up to 6.00×10^6(d. wt)	up to 6.60×10^5(d. wt)	-	(Unc and Goss, 2004)
Swine	1.10×10^6 to 5.90×10^7 (*E. coli*; d. wt)	-	-	(Kelley and Walker, 2000)
Poultry	1.32×10^6 to 1.30×10^8(d. wt)	-	6.2×10^5 to 1.07×10^8 (d. wt)	(Unc and Goss, 2004)

The concentration of pathogens in manure that is to be incooperated into soil is important as such pathogens can contaminate water sources (Unc and Goss, 2004), and may end up on the surface of produce particularly if concentrations of pathogens are high. The species and concentration of bacteria present in manure can be limited to a specific species of animal or particular conditions. For example, cattle manure has been known to be a reservoir for pathogenic strains of *E. coli* (Omisakin et al., 2003). It is thus important that famers are aware of elements that may aid the transportation and survival of pathogens in the soil (Unc and Goss, 2004).

2.12 Issues to be considered in capacity building programmes (produce hygiene quality) for small-scale farmers

Recommendations for appropriate manure management cannot be formulated without proper understanding of the dynamics that affects the transportation and survival of microorganisms in the different resources (Unc and Goss, 2004). It is therefore fundamental that farmers are well informed of the proper ways of composting manure, irrigation water management and proper pre- and post handling of produce (Baldwin and Greenfield, 2009; Brinton, 2000).

Basic knowledge of land, seed and water source history can aid in avoiding the introduction of contaminants during the farming process (Brackett, 1999). The control of insects and pests by planting plants with a strong ‘foul’ aroma for instance, can assist in limiting the spread of bacteria via the repelled insect vectors (Hashemi *et al*., 2009). The general hygiene of workers and equipment is good agricultural practice, leading via reduction of contamination to a better vegetable product less likely to cause sickness (Ko, 2010; Martins *et al*., 2012).

There is a general agreement that in order to achieve sustainability it is necessary that government, farmers and researchers engage (DAFF, 2011; Digbo and Momoh, 2007). This is to ensure that government has policies that support farmers and that the presence of subsidies facilitates sustainable practices (DAFF, 2011; Digbo and Momoh, 2007). Researchers and extension workers should encourage farmers to participate in the developments of sustainable technology as the farmers themselves are the end users (Ko, 2010).

When the levels of literacy are low the exchange of information and knowledge between the farmers, researchers and other stake holders becomes essential (Hashemi *et al*., 2009; Hendriks *et al*., 2009). According to Stefano *et al*. (2005), knowledgeable and skilled small-scale farmers are more likely to make informed decisions and to take appropriate action in organic farming.

The most ideal way to convey information to small-scale farmers is to build upon their indigenous knowledge by identifying similarities when adapting new concepts such as organic farming. Research collaborations are also important. Research on the different aspects of the organic farming process may facilitate the generation and sharing of knowledge (Hendriks *et al*., 2009).

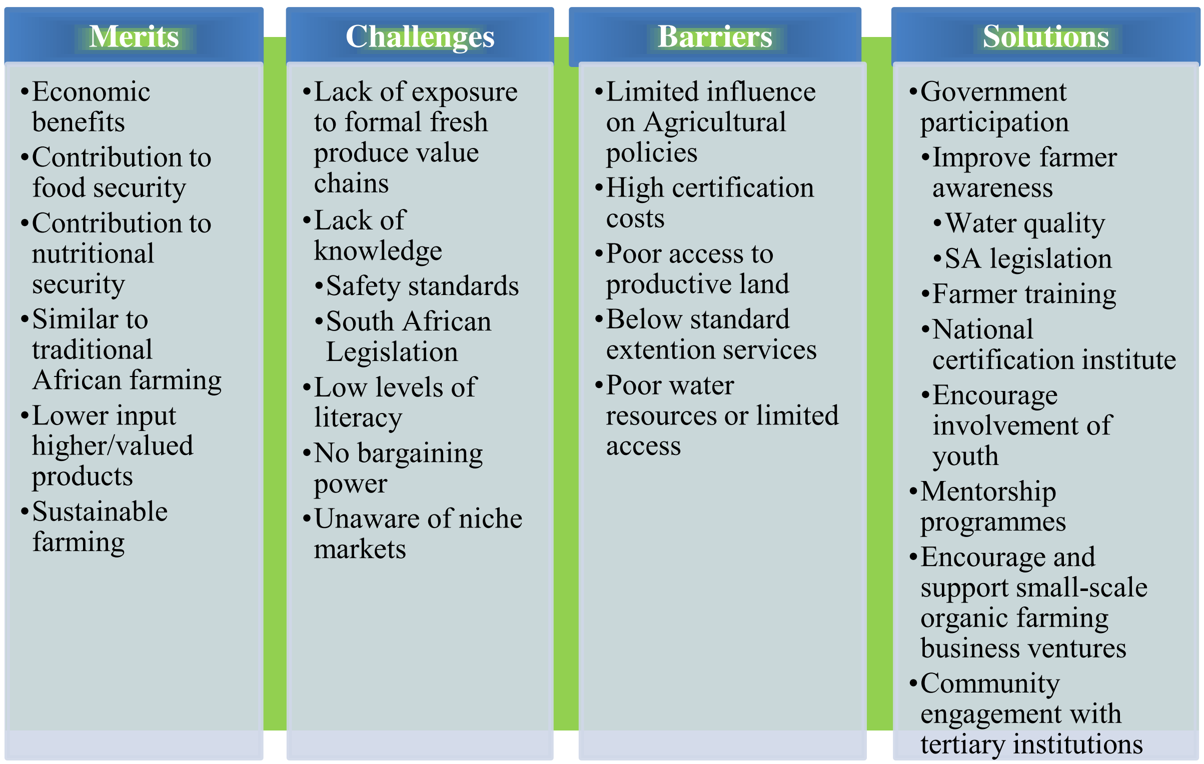

Figure 2.1: Enablers and barriers to the improvement of market access for rural small-scale aspirant organic producers

Government policies and programmes using a 'bottom-up' approach may play a primary role which is integral to the growth of the small-scale farming sector. South Africa is currently in the process of formulating policies that will govern organic farming practices in South Africa (DAFF, 2011). The implementation of these policies should at least lighten the load of challenges and constraints faced by South African small-scale farmers (Figure 2.1). An active effort of minimizing the risk of vegetable contamination has positive impacts on the organic farming value chain. Not only does it decrease losses due to unacceptable contamination levels but it also increases the credibility in terms of safety to the market. Only the proper implementation of good hygienic agricultural practices and appropriate knowledge concerning food safety may minimize the spread of potential pathogens endangering consumer health.

2.13 Conclusion

Small-scale organic farming has numerous documented merits. It is often identified as a means of generating income and thus providing farmers with livelihoods and contributing towards household food security. However, its success in South Africa is clouded by several barriers. One barrier is the limited access to quality resources such as irrigation water. Irrigation water of poor microbiological quality combined with farmers' limited knowledge of hygienic practices may negatively influence the quality of the final vegetable product. The use of animal manure in organic farming adds to the microbiological risks.

Bearing in mind the pathogen outbreaks in 2011, consumers are aware of the importance of hygiene and have a preference for produce of good hygienic quality. It is thus important for farmers to meet these quality standards in order to appeal to the market. Literature suggests that farmer training is a valuable tool in capacitating farmers on good farming practices. Farmer training can ultimately assist farmers in accessing markets and insuring food security as a result of producing good quality vegetables.

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Chapter 3

The Role of Socio-Economic Factors on Hygienic Practices in Small-scale farming: Towards Market Access for Improved Rural Livelihood

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Producing good quality produce is critical in improving market access and food security. Farming practices influence the quality of the final product, which in turn determines its success in the market. It is thus important that farmers produce food of good hygienic quality if they intend to participate successfully in the market. However, previously disadvantaged small-scale organic farmers in South Africa, who were largely excluded from formal fresh produce value chains in the past and are entering these value chains for the first time, are not familiar with food hygiene standards and farming practices. This has negative implications to their market access and food security situation. This study's aim, therefore, was to determine the extent to which socio-economic factors such as age, gender, level of education and training influence the hygienic farming practices employed by eTholeni small-scale organic farmers in uMbumbulu, KwaZulu-Natal. Data collection tools included key informant interviews and questionnaires administered to 73 uncertified organic farmers in uMbumbulu, KwaZulu-Natal. The questionnaire probed respondents' attitude s, hygienic practices and composting practices. Data analysis involved descriptive statistics such as the Chi-Square test and a logistic regression model.The results of descriptive analysis indicated that the majority of the farmers (60%) were female, most of which (73%) were above the age of 40. The logistic regression indicated that socio-economic factors such as education, training and farm income had a significant influence on the hygienic practices of small-scale farmers. This study showed that gender had no influence on the practices of the eTholeni small-scale farmers. Farmers who already receive some income from farming activities and those that had received training on hygienic farming practices were likely to wash hands and equipment prior to entering the field compared to those who had not. These results indicate that training, education and farming experience are important and effective tools in implementing good hygienic practices in small-scale farming. It is therefore recommended that policies should advocate for farmer training, not only for subsistence purposes, but with an aim of accessing produce markets.

Keywords: Small-scale; farmers; food hygiene; food safety; food security; market access

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3.1 Introduction and Background

Agricultural produce of good hygienic quality is important in the improvement of small farming enterprises and household food security (Soon & Baines, 2012).Small-scale farmers' contribution to agricultural output can be regarded as insignificant, with a contribution of less than 5% to South Africa's total agricultural output (Aliber & Hart, 2009). However, small-scale farming is thought to have a good potential of contributing significantly to food security through the sale of surplus produce to the markets (Chitja & Mabaya, 2012: 2; Stats SA, 2012: 1-7). Issues pertaining to good hygiene practices and exceptional Hygienic quality therefore become relevant in insuring the well-being of consumers.

Consumers have a preference for foods that meet high hygienic standards as it is unlikely to cause foodborne illnesses (Barrow, 2006:6; Martins *et al*., 2012). As a result, markets have stringent standards to ensure the hygiene quality of produce. These standards include the documentation of hygiene practices, the recording of training activities and the identification of potential hygiene hazards (GlobalGap, 2011). It is for this reason that farmers need to prioritize good hygienic practices in order to produce Grade A quality vegetables in line with the preferences of the market (Chitja & Mabaya, 2012: 5-6). Such a prioritization is essential as farming practices contribute to the quality of the final product, which in turn determines its success in markets (Louw *et al*., 2007).

Small-scale farmers face a number of challenges with regards to adopting good hygienic practices and accessing markets, particularly in the developing world (Chitja & Mabaya, 2012: 3). Barriers to markets include farmers' poor access to reliable and safe water resources, lack of knowledge and lack of financial assistance (Matshe, 2009; Thamaga-Chitja & Hendriks, 2008). These barriers may compromise good hygienic practices mainly because: farmers lack knowledge (Agwu & Edun, 2007) on the importance hygiene in the farming environment and resources readily available to the farmer, such as water, may already be microbially contaminated (Buck *et al*., 2003).

In South Africa, these barriers are worsened by the socio-economical distortions resulting from the legacy of apartheid. As a result of this legacy, historically disadvantaged small-scale farmers are entering value chains for the first time and are not familiar with food quality and safety standards (Louw *et al*., 2007; Thamaga-Chitja & Hendriks, 2008). These small-scale farmers are unaware of farming practices that are likely to catalyze the transition towards better market access (Louw *et al*., 2007; Thamaga-Chitja & Hendriks, 2008). This is unfortunate as lack of market access has been identified as a key driver of food insecurity (Matshe, 2009) and thus poor market access undermines the potential of farming activities to contribute to household food security as

Simple practices such as washing hands and farming equipment (watering cans, rakes, hoes, wheelbarrows, spade etc.) with water and soap before and after use are important in limiting the spread of possible contaminants (Martins *et al*., 2012; Soon & Baines, 2012). The washing of farming equipment is significant as farmers often have to share certain pieces of equipment because of limited resources. Issues of hygiene and subsequent microbial quality in the rural small-scale farming sector of South Africa are even more critical to note, given the policy drive to support and develop small-scale farmers in order to improve household food security and reduce poverty (Matshe, 2009; Stats SA, 2012: 1-7).

This research was conducted to investigate the socio-economic factors influencing the hygienic practices imployed by small-scale farmers. The paper looks at the extent to which these socio-economic factors influence farmers' hygiene practices. It is based on the assumption that produce of greater hygiene quality penetrates markets with greater ease as a result of its appeal to consumers. Therefore, farmers that are able to meet the required hygiene standards have the potential to improve household food security through improved access markets.

3.2 Research methods

Study site and sampling procedures

The study took place at eTholeni village in uMbumbulu, KwaZulu-Natal (29°59’27.9”S, 30°42’28”E). Data collection tools included key informant interviews from the uMbumbulu Agri-Hub, a local organic farming NGO and questionnaires administered to 73 subsistence farmers all living within the vicinity of the uMbumbulu Agri-Hub. The uMbumbulu Agrihub supplies vegetables under the “organically produced” and not “certified organic” label as the organization's produce is yet to be certified as organic. Questionnaires were used to collect information that would provide insight into the attitudes and behaviours of the small-scale farmers in the study.

Data analysis

Data was coded, captured and analysed using the IBM SPSS 21 and STATA 11 statistical packages. Descriptive statistics such as the Chi-Square test evaluated the significance of relationships between practices and relevant nominal or categorical socio-economic variables.

The logistic regression model was used to investigate the factors that influence farmer hygienic practice. Washing of hands and equipment was used as a proxy for hygienic practices. Farmers with good hygiene were defined as those who washed both their hands and equipment prior to entering the field. The hygiene variable will take the value 1 for households practicing good hygiene, and 0 otherwise.

The explanatory variables were the farmer's socio-economic factors such as gender, age, education level, incomes, and access to training. The model is as specified below:

$L_i = \ln [P_i/(1-P_i)] = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + ... + \beta_k X_{ki} + u_i$;

Where: i = 1, 2, ………n are the farmers; L is the logit; ln = natural logarithm; P_i = the probability of a farmer practicing good hygiene; $(1-P_i)$= the probability of a farmer not practicing good hygiene; X_{1i} …….X_{ki} are the farmer attributes; u_{ji} is the random error term; and β 's are the parameters to be estimated.

3.3 Results and discussion

Demographic and socio-economic characters

The results indicated that the majority (60 %) of the farmers were female, while 40% were male. This is in line with literature, which has indicated that women are the main participants of smallholder farming in South Africa (Aliber and Hart, 2009; Modi, 2003). Twenty seven percent (27%) of the respondents were below 40 years of age, while 73% of the respondents were ≥ 40. This demonstrates the fact that the youths and younger adults are shunning farming, going to other higher paying opportunities. Data analysis also showed that most of the farmers were literate. Only twelve percent (12%) of the farmers had no formal education, while 37% had a primary school education and 51% a secondary school education. The respondent's most common sources of income were farming (60.3%), social grants (37.0%) and pension (29%). Farming provided income for 60% of the participants with 78% of those farmers receiving revenues between R150- R250 per week. As evidence of income growth, more farmers were joining the Agri-Hub to be trained and then supply it. This result shows the potential of organic farming as a livelihood as poor farmers stand to gain economically (UNEP-UNCTAD, 2008:33; Wegner & Zwart, 2011:20-23).

Sample description

Gender vs. income source

There was a significant relationship at 10% (p=0.07) (see appendix) between income sources and gender. Chi-square tests indicated that woman received their main income from remittances, social grants and pensions. Men received most of their income from wage employment and farming income. This may result from the fact that man usually acquire wage employment whilst women take the roles of homemakers (Trauger *et al*., 2008).

Education level vs. income source

There was a significant relationship at 10% (p=0.06) between income sources and education levels. Chi-square results indicated that it is the less educated who are more likely to get income from sources such as farming, remittances and pensions. While the educated get their income from mainly wages (Serin *et al*., 2009). Improved education level increases the chances of getting wage employment (Agwu & Edun, 2007). Therefore the results are expected as those with lower levels of education are less likely to get jobs and are dependent on remittances and income from farming.

Relationships between farming practices and gender

The relationship between hygienic practices and gender was analysed using the Chi-Square test of independence. Table 3.1 tabulates the percentage of male respondents (out of a total of 29) and the percentage of female respondents (out of a total of 44) employing the farming practices. The p-value from the Chi-square test indicated that the relationship between gender and practices was statistically insignificant at 10% significance level.

Table 3.1: Relationships existing between farming practices and gender of farmers of eTholeni small-scale organic farmers (n=73[a])

	Gender		p-value
	Male	Female	
Hygienic practices prior to entering garden			
Individuals washing hands and boots	66%	68%	0.813
Individuals washing of farming equipment	72%	66%	0.558
Individuals who acknowledge the following possible sources of contamination			
Contaminated water	76%	64%	0.271
Incorrect composting techniques	69%	68%	0.944
Poor personal hygiene	62%	75%	0.239
Contaminated soils	62%	73%	0.233
Contaminated equipment	55%	61%	0.952
Type of treatment manure subjected to			
Drying of manure (*umquba*)	41%	52%	0.362
Composting	45%	55%	0.416
Direct use of wet/fresh manure	31%	18%	0.204

[a]composition of sample =29 male and 44 female

The p-value showed no statistically significant associations between gender and farming practices. The farming practices employed by the eTholeni small-scale farmers were therefore not influenced by gender. This may have resulted from interactions between male and female farmers which led to the adoption of similar farming techniques. These interactions are as a result of communal gardens and farming cooperatives that farmers grouped themselves into.

Relationships existing between farming practices and age of farmers

The respondents fell into different age categories. Table 3.2 summarizes the percentages of individuals in a particular age group employing the relevant farming activities. Respondents above the age of 40 possessed the most knowledge on the possible sources of contaminants and employed the best farming practices. The p-value indicated that there was an association between hygienic practices and age group of farmers.

Table 3.2: Relationships existing between farming practices and age of farmers of eTholeni small-scale farmer (n=73[a])

	Age		p-value
	<40	≥40	
Hygienic practices prior to entering garden			
Individuals washing hands and boots	50%	74%	0.056*
Individuals washing of farming equipment	50%	76%	0.037**
Individuals who acknowledge the following possible sources of contamination			
Contaminated water	55%	74%	0.012**
Incorrect composting techniques	55%	74%	0.127
Poor personal hygiene	55%	76%	0.089*
Contaminated soils	55%	64%	0.473
Contaminated equipment	50%	72%	0.081*
Type of treatment manure subjected to			
Drying of manure (*umquba*)	50%	47%	0.829
Composting	40%	55%	0.262
Direct use of wet/fresh manure	40%	17%	0.038**

**and * show significant relationships at 5% and 10% levels respectively; [a]composition of sample =20 < 40 and 53 ≥ 40

The results suggested that groups above the age of 40 were more likely to practice good hygiene. This was in line with common farmer traits associated with age suggested by Burton, (2006). Farmers above the age of 40 often employed hygienic practices as a result of farming experience (Burton, 2006). According to the data, respondents over 40 had the most knowledge on sources of contamination. This is in line with the findings of Martins *et al*., (2012) who reported that individuals belonging to the older age have good knowledge of food handling practices. Lower participation by individuals belonging to the <40 category is often associated with youth disinterest in farming activities (Modi, 2003). Aliber & Hart, (2009) attempt to disprove this perception accounting it to the actual size of the youth cohort, because there are more young people percentages disguise the actual numbers when compared to the smaller cohort of older people.

Relationships existing between farming practices and trained farmers

Only 45% of the 73 respondents that supplied the uMbumbulu Agri-Hub had received training on a number of farming practices, which included composting, hygienic practices and soil management. Table 3.3 indicates the percentage of trained (out of a total of 33) and untrained individuals (out of a total of 44) that carried out the different practices. The difference in percentages between trained and untrained caused a distinct variation in the farming practices of the two groups. The treatment of manure into *Umquba* did not show significant association with training. All other hygienic farming practices had significant relationships with training.

Table 3.3: Relationships existing between farming practices and training of farmers of eTholeni small-scale organic farmers (n=73[a])

	Trained	**Not trained**	**p-value**
Hygienic practices prior to entering the garden			
Individuals washing hands and boots	91%	48%	0.000***
Individuals washing of farming equipment	91%	50%	0.000***
Individuals who acknowledge the following sources of contamination			
Contaminated water	82%	58%	0.026**
Incorrect composting techniques	94%	48%	0.000***
Poor personal hygiene	91%	53%	0.000***
Contaminated soils	82%	45%	0.001***
Contaminated equipment	85%	50%	0.002***
Type of treatment manure subjected to			
Drying of manure (*umquba*)	55%	43%	0.305
Composting	76%	30%	0.000***
Direct use of wet/fresh manure (no treatment)	9%	35%	0.009***

and * show significant relationships at 5% and 1% levels respectively; [a]composition of sample =33 trained and 40 not trained

According to key informants, farmers who have attended at least two or more workshops were eligible to supply the uMbumbulu Agri-Hub and were thus registered in the farmer database. It is clear from the difference in percentages that training has an effect on practices employed. The table (Table 3.3) suggests that trained members of the Agri-Hub were knowledgeable and showed insight on potential contaminants in the farming system. This is proved by the relationship that exists between hygienic practices ($p< 0.01$), knowledge of contamination sources ($p < 0.01$ and 0.05) and treatment animal manure is subjected to ($p< 0.01$ and 0.05). These findings highlight farmer behavioural changes leading to better farming practices as a result of training (Ko, 2010; Martins *et al*., 2012). This, according to key informants, also highlights on the farmers discipline focus and overall willingness to learn. The use of wet/fresh manure in the farming process shows significance at 0.01 and 0.05, this implies that this practice is dependent on training. The differences between trained and untrained farmers were similar to the findings of Yang *et al*.,(2008). In this study conducted in China, farmers had limited knowledge of the natural enemies of their produce prior to training. After training, farmers were more knowledgeable on the natural enemies and produced significant results ($p< 1\%$, 5% and 10%) confirming relationships between knowledge and training (Yang *et al*., 2008).

Relationships existing between farming practices and farmer level of education

The respondents fell into different categories of level of education. Twelve percent (12%) of the farmers had no formal education, 37% had a primary school education and 51% listed secondary school as their highest level of education. Table 3.4 indicates the percentage of individuals possessing different levels of education. Farmers who had received a primary and secondary level education often practiced good hygienic practices when compared to farmers with no formal education. Hygienic practices showed significance at 5 and 10% significance levels.

Table 3.4: Relationships existing between farming practices and farmer level of education of eTholeni small-scale farmers (n=73[a])

	Level of Education			
	No formal education	Primary	Secondary	p-value
Hygienic practices prior to entering garden				
Individuals washing hands and boots	11%	48%	54%	0.067*
Individuals washing of farming equipment	11%	33%	60%	0.012**
Individuals who acknowledge the following possible sources contamination				
Contaminated water	44%	74%	70%	0.370
Incorrect composting techniques	33%	78%	70%	0.110
Poor personal hygiene	56%	70%	73%	0.307
Contaminated soils	67%	70%	62%	0.081*
Contaminated equipment	56%	63%	62%	0.849
Type of treatment manure subjected to				
Drying of manure (*umquba*)	56%	44%	49%	0.769
Composting	56%	44%	60%	0.249
Direct use of wet/fresh manure	22%	26%	22%	0.657

*and ** show significant relationships at 10% and 5% levels respectively [a]composition of sample =9 no formal education, 27 primary, 37 secondary

The data suggested (by means of percentage) that farmers who posses primary and high school education practice the best farming practices when compared to those who have received no formal education. Farmers with higher levels of education are thought to posses more knowledge of good farming practises (Martins *et al*., 2012). These results (Table 3.4) reflect this as farmers with no formal education often do not carry out good hygienic practices and have limited knowledge of sources of contamination. Though school education and onsite training are expected to yield different results (Serin *et al*., 2009), the skills acquired through formal education may assists farmers in problem solving.

Logistic regression analysis results

The logistic regression model was done to investigate the socio-economic factors explaining the probability of farmers adopting good hygienic practices. Washing hands and equipment was used as a proxy for good hygienic practices. The results of the logistic regression model are presented in Table 3.5.

Table 3.5: Factors influencing farmer's hygienic practice of washing hands and equipment: Logistic regression results

Variables	Coefficient		Marginal effects	
	Value	Std. Err.	Value	Std. Err.
Gender	0.6384	0.8168	0.0827	0.1041
Age	0.3567	1.1089	0.0462	0.1431
Education level				
Primary education	-2.7181**	1.3390	-0.3521**	0.1564
No education	-3.2924*	1.9662	-0.4265 *	0.2394
Main income source				
Remittances	-0.7316	1.0798	-0.0948	0.1383
Farm activities	2.0109**	0.9626	0.2605**	0.1119
Grant	0.9547	0.8841	0.1237	0.1119
Pension	-0.3596	0.9352	-0.0466	0.1207
Wages	-0.2504	0.9889	-0.0324	0.1278
Produce to sell	1.22912	0.8487	0.1592	0.1031
Food safety awareness	0.4372	0.9348	0.0566	0.1202
Training	2.4998**	1.1645	0.3238**	0.1347
Training from government	-1.0367	0.9796	-0.1343	0.1233
_cons	-2.9135	2.4447		
Pseudo R^2 = 0.4191				
LR χ^2 = 42.41* **				

*, ** and *** show significant relationships at 10%, 5% and 1% levels respectively

Table 3.5 indicated that farmer's education level positively influences hygienic practices. Farmers with primary or no education were found to be less likely to practice good hygiene compared to those with secondary education. Farmers with a primary education had a 35% less chance of carrying out good hygiene compared to those with secondary education. Similarly, farmers with no education had a 43% less probability of carrying out good hygiene compared to those with secondary education.

The analysis also showed that farmers that received most of their income from farming had 26% (significant at 5%) more likelihood of adopting good hygienic practices compared to those receiving little or no income from farming. Furthermore, farmers who had received training were 32% more likely to practice good hygienic compared to farmers who were not trained. This emphasizes the importance of training and equipping farmers with skills and knowledge that allow them to execute good farming practices.

The institution where training was received was insignificant; indicating that what is important is training and not the source. Age was expected to be significant in-line with the Chi-square test, its insignificance in the Logistic regression is difficult to explain but may be influenced by the presence of the other variables in the model.

The R^2value was 42% implying that the model explains 42% of the variation in the data. Although this R^2 value is relatively low, it is acceptable in cross-sectional data (Kuwornu & Owusu, 2012).The model as a whole was significant at 1% as indicated by the LR χ^2 value.

Proposed interventions for improved farmer hygiene

A number of interventions were proposed by farmers to assist in improving their hygienic practices. Thirty six percent (36%) of respondents recommended interventions by the departments of water affairs (DWAF) and agriculture (DAFF), followed by 30% who suggested workshop and training. Thirty five percent (35%) of farmers felt that there was enough awareness with issues surrounding farmers' hygiene and therefore felt that interventions were unnecessary.

Table 3.6: Percentage of respondents who agree with proposed interventions for improved farmer hygiene

Interventions and Training required	Percentage of respondents who agree
Interventions by Departments of Health and Agriculture Awareness on types of diseases, potential sources, prevention and control of microbiological contaminants in the organic farming system.	8%
Workshops and training Hygeine quality in organic farming to ensure farmers employ practices that minimize bacterial contamination.	30%
Interventions by Dept. of water Affairs and Dept. of Agriculture Should your irrigation source be contaminated what other irrigation alternatives are available. Irrigation water management	36%
No interventions, enough awareness	35%

Thirty five percent (35%) of respondents felt that there was enough awareness on vegetable quality in the eTholeni community. The uMbumbulu Agri-Hub was largely responsible in raising this awareness and suggesting farming practices that promote the farmer hygiene and overall microbial quality of vegetables. Furthermore, respondents suggested that interventions by governmental departments of health and agriculture would be beneficial. Such interventions would highlight sicknesses associated with vegetable contamination and South African agricultural legislation and standards. Respondents also emphasized the importance of interventions by the department of water affairs for irrigation purposes. This is important as a result of climate change and water scarcity (Wegner & Zwart, 2011:3-5). Most participants recognised the importance of understanding standards in improving market appeal for their small enterprises (Louw *et al*., 2007).

3.4 Conclusion

The present analysis suggests that the level of education and training of farmers has a considerable influence on the farming practices that they employ. The fact that the uMbumbulu Agri-Hub only considers produce from trained farmers is testament to this. Training programmes are fundamental in equipping farmers, particularly small-scale farmers with knowledge that is necessary in the selection of methods and processes appropriate for their individual farming needs. The logistic regression indicated a number of socio-economic variables that significantly improve the likelihood of farmers practicing good hygiene. Variables that increased the probability of farmers washing hands and equipment prior to entering the field are: Income from farming activities, education and receiving training on hygienic farming practices.

The study indicates how training, education and farming experience are important and effective tools in implementing good hygienic practices in small-scale farming. The study's main recommendation is that policies should advocate for small-scale farmer training. This training should not be limited to subsistence purposes, but should also aim at preparing farmers towards accessing produce markets. Farmer training in hygienic practices should aid farmers to meet the stringent market standards allowing for better access, the regular income from such activities support farming as a livelihood and bearer of food security.

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Chapter 4

Investigation of the hygienic quality of water, compost and leafy vegetables produced by organic small-scale farmers in uMbumbulu (rural KwaZulu-Natal, South Africa): Implications for market access and capacity enhancement

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Small-scale farmers are increasingly becoming important in food production in South Africa but have not participated in formal food value chains and thus food quality and safety issues are of concern. The study investigated the hygienic quality of leafy vegetables produced by four farmer co-operatives supplying the local Agri-Hub in uMbumbulu in KwaZulu-Natal, South Africa. Microbiological testing was conducted on irrigation water, compost and leafy vegetables (lettuce and spinach) produced by the Jabulani, Nungwane, Senzakahle and Siyazenzela cooperatives. The cooperatives used Tap, Dam, Spring and River water. Laboratory analysis was conducted once a month during the critical months of October, November and December where highest sales of Agri-Hub fresh produce are observed. The quantification of selected hygiene indicator organisms (total and faecal coliforms including *Escherichia coli*) was carried out using the most probable number (MPN) technique. Microbiological analysis revealed that the irrigation water sources, vegetables and compost faecal coliform levels met national and international standards with irrigation water having MPN values of <1000/100ml for faecal coliforms, vegetable MPN values of <200/g for total coliforms and *E. coli* MPN values per-g below the limit of detection. Compost had MPN values of<1000/g for faecal coliforms. This study provides initial information indicating that the irrigation water used by Agri-Hub small scale farmers meets the World Health Organization (WHO) recommendations for safe irrigation regarding faecal coliforms and that the vegetables produced by Agri-Hub small scale farmers meet the requirements for total coliforms set by the South African Department of Health. Furthermore, this study reiterates the importance of interventions that build capacity of small-scale farmers for market access of formal value chains. Statistical analysis revealed the importance of farmer training. It is therefore recommended that policies encourage farmer awareness on their responsibility of producing good quality vegetables. It must also be noted that farmers require support in attaining the various resources needed in order to successfully and continually supply markets.

Keywords: Small-scale farmers; organic farming; food security; food safety; hygiene indicator organisms; coliforms; irrigation

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4.1 Introduction

In South Africa, small-scale organic farmers are increasingly becoming important in food production. However, previously disadvantaged farmers have not participated in formal South African value chains and thus have limited knowledge of market specification and standards (Louw et al. 2007). These small-scale organic farmers rarely supply larger markets, as a result of their inability to consistently produce large volumes of vegetables that meet various quality standards which include those of hygiene quality (Louw et al. 2007).

Organic farming (i.e. farming without use of synthetic pesticides and chemical fertilizers; this farming may employ the use of livestock manure) in particular is said to have positive potential outputs for small-scale farmers world-wide, especially with consumer's renewed interest in healthy foods such as fresh fruits and vegetables (Berger et al. 2010;UNEP-UNCTAD 2008;Wegner and Zwart 2011). Farming practices may be prone to microbiological contamination as seeds, irrigation water and manure have been identified as possible source of contamination in such farming systems (Buck et al. 2003). This is thought to be partially attributed to the absence of chemical treatments (such as chemical fertiliser) that may reduce the microbial load (Oliveria et al. 2010). Though compost standards are not well defined, the importance of practicing correct composting techniques in order to decrease possible microbial contamination is acknowledged (Brinton 2000). This is especially important in the production of leafy vegetables such as lettuce and spinach which are regarded as high risk produce often eaten without further processing.

Microbially contaminated water sources in KwaZulu-Natal have been suspected to aid in the transfer of pathogens when overhead irrigation is used (Gemmell and Schmidt 2010, 2012). According to Berger et al. (2010), drip irrigation may be a safer option when compared to sprinklers or spray irrigation as surface contamination and biomass build up is avoided. In addition, this will help to avoid internalization of potential pathogens present on the plant surface (Deering et al. 2012).

Pathogenic strains of *Escherichia coli* as well as *Salmonella* spp. and *Shigella* spp. have been associated with a number of bacterial outbreaks (Frank et al. 2011;Gemmell and Schmidt 2010; MMWR, 2011;Niehaus et al. 2011). *E. coli* outbreaks were reported in Japan in 1996 and the USA in 2006 due to contaminated radish sprouts and pre-packaged spinach respectively (Berger et al. 2010). More recently, Europe saw a severe outbreak of haemolytic uraemic syndrome (HUS) caused by *E. coli* (STEC) (Frank et al. 2011). Contaminated fenugreek seeds from Egypt were identified as the vehicles of transmission of STEC (EFSA 2011).

Consumers who are young, old, pregnant and immune-compromised (YOPI) are particularly vulnerable to such outbreaks as a result of their weakened immune systems (Gemmell and Schmidt 2010). Organic farmer knowledge of microbiological standards is therefore important in not only minimizing such outbreaks but meeting the stringent market standards (MMWR 2011).

Faecal coliforms are hygiene indicator organisms commonly used to determine the hygiene quality of water and produce as they are regarded as a reliable means of determining faecal contamination and the possible presence of enteric bacterial pathogens (Bezuidenhout et al. 2002; WHO 2006, WHO 2011). Among these so called faecal coliform bacteria, highly pathogenic toxin forming strains of *E. coli* such as STEC or EHEC are a major concern (Gemmell and Schmidt 2010; Little and Gillespie 2008).

Farmers need to be well informed of practices that may increase the risk of microbiological contamination of water and produce. The building of capacity in areas such as water safety, correct composting techniques and good personal hygiene all need to be addressed (Digbo and Momoh 2007).

4.2 Materials and methods

Site location and Data collection – uMbumbulu farmer survey

The 4 small scale farmer cooperatives Jabulani, Nungwane, Senzakahle, and Siyazenzela assessed in this study were all situated in uMbumbulu (KwaZulu-Natal) within a 2 km vicinity of the Agri-Hub (29°59’27.96“S, 30°42’28.8”E).

The survey interviewed 73 farmers living within the uMbumbulu vicinity. Some of these farmers were working with the uMbumbulu Agri-Hub, which focuses on providing training on all aspects of the organic farming value chain and also purchases farmers produce. The AgriHub then supplies vegetables under the “organically produced” and not “certified organic” label as the organization's produce is yet to be formally certified as organic. This study worked with 33 farmers supplying the Agri-Hub and belonging to the Jabulani (12/73), Nungwane (3/73), Senzakahle (10/73) and Siyazenzela (8/73) cooperatives. The rest of the numbers (40) were made up of untrained farmers yet to supply the Agri-Hub. The questionnaires were prepared in IsiZulu and English which provided insight into farmers' attitudes, behaviours, and general hygiene practices when farming.

Sample collection for Microbiological Analysis

Water , compost and vegetable samples were collected and analysed once a month over a period of three months. Water was obtained using a sterile 1 L Schott bottle from areas of fast flow (for river water) at a depth half that of the total in order to avoid debris and collecting exclusively surface water. In the case of tap water, 1 ml of $Na_2S_2O_3$ solution containing 18 mg of the pentahydrate was added to the sampling flask prior to autoclaving in order to neutralize the incoming free chlorine atoms found in the tap water. About 20 g of spinach, lettuce and compost samples were collected aseptically at the study sites and placed into sterile Erlenmeyer flasks. Leaf samples were collected by removing not less than 20 g of produce material from at least three different plants. To avoid soil based contamination, material close to the soil surface was avoided. Compost from the top part of the compost heap was taken for analysis as farmers usually use this material for fertilization as stated by key informants. All samples were stored and transported on ice and analysed in the laboratory within 2 h. The physico-chemical characteristics of the water were measured on-site. Temperature and pH of water samples were measured on the field using a calibrated pH/°C meter (Hanna instruments, HI8314, Italy). Chemical oxygen demand was determined using the Merck NOVA 60 system (Germany) and a Merck COD test kit (25–1500 mg/L, Merck) according to the manufacturer's instructions.

Methods for Microbiological analysis

Total and faecal coliforms as well as *E. coli* in water and produce samples were enumerated by using the MPN (most probable number) method MFHPB-19 according to Health Canada (2002). This well-established MPN procedure was employed to quantify the selected hygiene indicators (i.e. total coliforms, faecal coliforms, *E. coli*) as follows: For water samples, each of five tubes of 10ml double strength LST (Lauryl Sulphate Tryptose broth, Merck) were initially inoculated with 10ml undiluted irrigation water samples. The irrigation water samples were then diluted tenfold by aseptically pipetting 1 ml of the water sample into 9 ml of sterile 0.1% buffered peptone water (Merck) followed by subsequent decimal dilution (up to 10^{-4}) using the same diluent. Produce and compost samples were prepared for analyses by adding 90 ml of 0.1%

buffered peptone water solution to 10 g (fresh weight) of leaf/compost material in a sterile Erlenmeyer flask followed by a 10 min treatment on an orbital shaker (MRC) at 200 rpm and at ambient temperature prior to decimal dilution (up to 10^{-8}) using the same diluent. Confirmation for total coliforms was done by inoculating Brilliant-green lactose bile broth (BGLB, Merck) using one loopful from gas-positive LST tubes. Faecal coliforms were quantified by inoculating gas-positive LST tubes into *E. coli* (EC) broth (Merck) followed by incubation at 44.5°C. *E. coli* was confirmed using gas positive EC broth tubes obtained to inoculate Levine-Eosin Methylene Blue (L-EMB) agar (Conda) and performing the prescribed biochemical confirmation tests – GIMViC [i.e. gas production at 45 °C (G), indole formation from tryptophane (I), Methyl-Red (M), Voges-Proskauer (Vi) and Simmon's citrate assimilation (C)]. *E. coli* ATCC 8739, *Pseudomonas aeruginosa* ATCC 9027 and *S*. Typhimurium ATCC 14028 were used as controls.

Survey statistical analysis

Questionnaire data was coded and analysed using IBM SPSS 21. Descriptive statistics (Chi-Square) test evaluated the significance of relationships between practices and farmer training.

4.3 Results and discussion

Farmer responses on vegetables produced

The questionnaire respondents produced an array of vegetables. These vegetables included beetroot, cabbage, carrot, green beans, lettuce, onions, pepper potato and spinach (Figure 4.1). All 73 respondents consumed the vegetables personally, with some selling surpluses to the community or the uMbumbulu Agri-Hub. A total of 87.7 % of all farmers who participated in the study farmed beetroot and 84.9 % produced cabbage and carrot. Onions and turnips were the least farmed vegetables as only 4.1% of the respondents produced them (Figure 4.1).

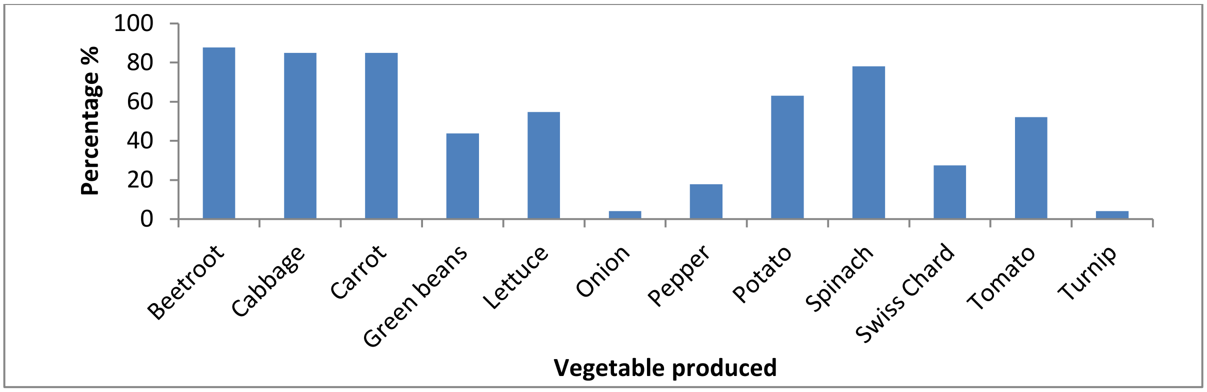

Figure 4.1: Most produced vegetables by farmers who participated in the survey (Multiple vegetables per respondent) n=73 Y-axis represents percentage of participating farmers

The choice of vegetables produced was largely motivated by personal preference, nutrition, health, customer demand, and affordability. Respondents cited that the affordability of seedlings and their understanding of the production system of vegetables resulted in the preference of certain vegetables over others. In this case, these farmers were well versed in using organic farming principles in their chosen vegetables. A similar study conducted in Embo, uMbumbulu concluded that a farmers decision to produce organic vegetables was also influenced by perceptions that organic produce was more nutritious and safe (Modi 2003).

Discussions with the key informants revealed that the primary objective for the farming of these vegetables was to improve the food and nutritional security of their families. This statement was confirmed by respondents who all admitted to consume the vegetables produced at a household level. Selling vegetable surplus for economic gain was encouraged only once the primary objective was fulfilled. The United Nations (UN) shares similar views, as it associates the implementation of small-scale organic farming with improved levels of household food security and the improvement of the quality of life (UNEP-UNCTAD 2008;Wegner and Zwart 2011).

There was a noted absence of traditional vegetables such as *amadumbe* (Taro) and *ubhatata* (Sweet potato) in the gardens. Farmers supplying the Agri-Hub attributed the lack of traditional vegetables like sweet potato to the fact that their market did not prefer these types of vegetables and subsistence farmers reported that the absence of traditional vegetables was a result of attack by *amaThendele* (wild birds) and *iMpunzi* (buck). The farmers produce vegetables that are demanded by the South African market, this is important in making their vegetables attractive to procurement specialists and organic produce supermarkets (Louw et al. 2007).

Irrigation water sources identified in farmer survey

Questionnaire responses identified 7 irrigation water sources (Table 4.1). The main irrigation water source supplying 42.5% of respondents was municipal supplied and treated tap water followed by river water (19.2%), dam water (16.4%) and spring water (9.6%), these were the irrigation water sources microbiologically tested in the study. Borehole, wetland and tank water was the least used, with a total of 12.3% of the respondents using these sources, they were therefore not tested in this study. All farmers used watering cans to irrigate their produce. A total of 72.6% of respondents acknowledged water as a source of contamination in the farming environment. The water sources, frequency of use and percentage of the respondents utilizing them are tabulated in Table 4.1.

Table 4.1: Irrigation water sources in descending order as identified by the respondents.

Source	Frequency ∑=73	Percentage %
Tap water	31	42.5
IsiJodi River	14	19.2
Nongwane Dam water	12	16.4
Spring water	7	9.6
Borehole	4	5.5
Wetland	3	4.1
Tank water	2	2.7

Most respondents used tap water as a source of irrigation, the reason for this is that all the areas under study had access to municipal supplied running water. Some farmer's preferred the use of natural water sources as they came at no financial cost, however, the natural water sources did not undergo any treatment prior to irrigation use. Discussions with the key informants revealed that the Agri-Hub thoroughly rinsed vegetables prior to sale using local tap water as a form of mitigation against possible unsafe material and due to concern and uncertainty on whether natural water sources met water quality standards.

The importance of farmer training

Only farmers who had received this training were allowed to supply the Agri-Hub, these farmers made up 45% of the study's respondents (33 a total of 73). These trained farmers are reffered to as 'Agri-Hub members'. Farmers received training on farming practices that included composting, hygienic practices and soil management. Table 4.2 reveals the practices and knowledge of farmers belonging to the Agri-Hub (out of 33) and those yet to join (out of 44). The difference in numbers between trained and untrained caused a distinct variation in the farming practices of the two groups.

Table 4.2: Relationships existing between practices and training of farmers of small-scale organic farmers.

	Agri-Hub members (out of 33)	Non-Agri-Hub members (out of 40)	p-value
Hygienic practices prior to entering the garden			
Individuals washing hands and boots	30	21	0.000***
Individuals washing of farming equipment	30	22	0.000***
Individuals who acknowledge the following sources of contamination			
Contaminated water	27	26	0.026**
Incorrect composting techniques	31	21	0.000***
Poor personal hygiene	30	23	0.000***
Contaminated soils	27	20	0.001***
Contaminated equipment	28	20	0.002***
Type of treatment manure subjected to			
Drying of manure (*umquba*)	18	19	0.305
Composting	25	13	0.000***
Direct use of wet/fresh manure (no treatment)	3	15	0.009***

** and ***show significant relationships at 5% and 1% significance levels respectively

According to key informants, farmers who have attended at least two or more workshops were eligible to supply the uMbumbulu Agri-Hub and were thus registered in the farmer database. Trained farmers (i.e. farmers' part of the Agri-Hub) appeared to be more knowledgeable on practices that could introduce contamination into their gardens. In addition Agri-Hub members practiced good hygiene and composted manure before use. Farmers not supplying the Agri-Hub were unclear on practices introducing microbiological contamination into gardens and avoided making compost heaps because of its physically demanding nature. Instead, farmers that were not a part of the Agri-Hub mainly used dried or wet manure, from different animals, in their farming practices. The Chi-square test indicated that trained Agri-Hub members were more likely to carry out good farming practices and had better farming knowledge than those who were non-members of the Agri-Hub. These relations were significant at 1% and 5% significance levels.

Physico-chemical characteristics of irrigation water sources tested

Laboratory trials were undertaken to investigate the hygienic quality of water used for irrigation. Findings revealed that the highest water temperature observed was for spring water with 23.9°C in October 2011 and the lowest for tap water with 18.0°C in November 2011. Conversely, the lowest pH was detected in spring water (6.5, October 2011) and the highest pH of 7.8 in tap water (November 2011). The detected chemical oxygen demand (COD) values oscillated within a range of 39 mg/L for October 2011 (spring water) and 14 mg/L (dam water, October 2011 and tap water, November 2011). The water temperature, pH and COD for each of the water sources for the months of October, November and December are tabulated on Table 4.3.

Table 4.3: Physico-chemical characteristics of irrigation water sources tested in the months of October, November and December 2011.

Month		Irrigation Water Source			
		Nungwane Dam water	Spring water source	IsiJodi River water	Tap water
October 2011	Water temp.	23.1°C	23.9°C	18.4°C	19.0°C
	Water pH	7.7	6.5	7.6	7.3
	Water COD	14 mg/L	39 mg/L	25 mg/L	17 mg/L
November 2011	Water temp.	23.8°C	22.0°C	19.3°C	18.0°C
	Water pH	7.2	6.5	7.1	7.8
	Water COD	17 mg/L	36 mg/L	36 mg/L	14 mg/L
December 2011	Water temp.	23.5°C	23.0°C	19.8°C	18.8°C
	Water pH	7.5	6.5	7.5	7.7
	Water COD	18 mg/L	36 mg/L	17 mg/L	17 mg/L

The pH values observed for the water sources (Table 4.3) were all within the acceptable range of 6.5-8.5 stipulated for agricultural use by the South African Department of Water Affairs (DWAF

1996). The elevated temperatures of the Nungwane Dam and the spring water when compared to river and tap water might be due to the fact that these water sources are stagnant. The chemical oxygen demand (COD), an indicator of organic pollutants in water showed values of between 14 mg/L and 39 mg/L (Table 4.3), indicating that the chemical burden of the water was within the range of the DWAF standard (DWAF, 2006).

Hygienic quality of irrigation water sources

Following the physico-chemical analysis, the microbial burden was established for the irrigation water by targeting bacterial hygiene indicators. The MPN for total coliforms in the dam, spring, river and tap water ranged from 7.9 to 110.00 per 100 ml while faecal coliform MPN values ranged from 2.0 to 27.0 per 100 ml. Tap water samples showed no detectable total or faecal coliforms and no *E. coli* was isolated.

Table 4.4: Most probable number (MPN) per 100 ml for total and faecal coliforms as well as *E. coli* in the irrigation water sources for the months of October, November and December 2011.

	October 2011		November 2011		December 2011	
Source of irrigation water	MPN/100ml	95% confidence interval lower / upper limit*	MPN/100ml	95% confidence interval lower / upper limit	MPN/100ml	95% confidence interval lower / upper limit
Total coliforms						
Nungwane Dam	7.90	2.4/25	7.90	2.4/25	7.90	2.4/25
Spring water	110.00	39/300	79.00	25/247	110.00	39/300
IsiJodi River	110.00	39/300	25.00	11/62	33.00	11/99
Tap water source	n.d	-	n.d	-	n.d	-
Faecal coliforms						
Nungwane Dam	2.00	0.28/14	4.50	1.1/18	4.50	1.1/18
Spring water	14.00	5.5/34	4.50	1.1/18	4.50	1.1/18
IsiJodi River	27.00	11/64	4.50	1.1/18	7.90	2.4/25
Tap water source	n.d	-	n.d	-	n.d	-
E. coli						
Nungwane Dam	n.d	-	n.d	-	n.d	-
Spring water	n.d	-	n.d	-	n.d	-
IsiJodi River	n.d	-	n.d	-	n.d	
Tap water source	n.d	-	n.d	-	n.d	-

*95% confidence limits calculated according to Garthright and Blodgett (2003) n.d- not detected (limit of detection is 2/100ml)

The levels observed in all the water sources were within the South African and WHO standards for the safe use of water for irrigation. According to these guidelines, the burden of faecal coliforms in water intended for agricultural use should not exceed 1000 per 100ml (DWAF 1996; WHO 2006). As was expected for the tap water, both total and faecal coliforms were below the detection limit of the MPN method since tap water has to meet the strict drinking water requirements.

The faecal coliform MPN values for the Nungwane dam, spring water and IsiJodi River indicated an unlikely risk for human health in the months of October, November and December of 2011. It appears therefore that all the tested irrigation water sources are microbiologically safe for the irrigation of vegetables during these months.

Hygienic quality of compost

Only 52.1% of the 73 respondents were reported to compost animal manure and other organic matter. All composts prepared contained livestock manure, constituting as much as 1/3 of the compost heap. Respondents used manure from cattle, chicken and sheep, with some respondents using a combination of manure from these animals.

Sixty six percent (71%) of the total respondents were aware of the fact that compost could be a source of microbiological contamination (see Table 4.2). Laboratory analysis using the MPN method aimed to establish the number of total and faecal coliforms including *E. coli* present in compost. The MPN of total coliforms in the compost from the 4 different locations ranged from 22.10 to 1 405.60/g and the MPN for faecal coliforms did not exceed 313.90/g. The highest *E .coli* levels were recorded for Nungwane in October (27.80/g). It is evident from Table 3.5 that the compost from Nungwane and Senzakahle cooperatives had the highest total coliform coliform values with about 1405.60/g in the month of October 2011. The Siyazenzela cooperative had the lowest levels of total coliforms which remained at about 22.12/g for all three months. The month of October 2011 had the highest abundance for coliforms, faecal coliforms and *E. coli* in compost samples, all of which decreased from October – December 2011(Table 4.5).

Table 4.5: MPN per g for total and faecal coliforms as well as *E. coli* in the compost of the different farmer groups for the months of October, November and December 2011.

Source of Compost	October 2011 MPN/g	October 2011 95% confidence interval lower / upper limit*	November 2011 MPN/g	November 2011 95% confidence interval lower / upper limit	December 2011 MPN/g	December 2011 95% confidence interval lower / upper limit
Total coliforms						
Nungwane	1405.60	561.44/3527.98	313.90	107.39/919.63	221.20	89.59/547.02
Senzakahle	1405.60	561.44/3527.98	278.10	117.46/659.73	27.80	11.74/65.95
Siyazenzela	22.10	8.96/54.68	22.10	8.96/54.68	22.10	8.96/54.68
Jabulani	943.50	349.69/2551.18	140.60	56.12/352.65	22.10	8.96/54.68
Faecal coliforms						
Nungwane	313.90	107.39/919.63	2.60	1.13/6.20	1.40	0.55/3.47
Senzakahle	22120	89.59/547.02	140	0.55/3.41	1.40	0.55/3.41
Siyazenzela	2.20	0.88/5.32	1.70	0.65/4.41	2.20	0.88/5.32
Jabulani	27.80	11.74/65.05	1.10	0.39/2.95	1.00	0.39/2.95
E. coli						
Nungwane	27.80	11.74/66.0	2.60	1.13/6.20	2.60	1.13/6.20
Senzakahle	22.10	8.96/54.7	2.60	1.1/36.20	1.40	0.55/3.47
Siyazenzela	1.40	0.55/3.5	n.d	-	n.d	-
Jabulani	2.60	1.13/6.20	1.10	0.39/2.95	n.d	-

*95% confidence limits calculated according to Garthright and Blodgett (2003) n.d- not detected (limit of detection is <0.02/g)

Though consensus has not been reached stipulating compost standards (Brinton 2000), the Code of Federal Regulations (CFR) from the US EPA proposes that biosolid based composts should have faecal coliforms levels not exceeding 1000/g if it is to be used as fertilizer (US EPA 1993). This standard was used to assess the bacterial numbers detected in the compost samples tested.

All the compost samples from the 4 cooperatives met this American standard for faecal coliforms. The respondents indicated that composting was an intricate process requiring a lot of time and patience at least for the 3 months being tested. The making of compost involved the digging of shallow trenches; these were filled by continuous layers of tree branches, green leaves and grass, wet animal manure, rotten food, cardboard, some watering and occasionally wood ash. Often, a hole is made in the middle using a pole and the height of the heap is at the discretion of the farmer. These compost heaps were abandoned for 3-6 months, according to the farmers it was virtually impossible to use the compost within this period as the compost was too hot and would damage any seed planted. Discussions with key informants suggested that the making of a compost heap is a very physical process and as a result farmers may sometimes do it incorrectly. Incorrect composting may cause the maturing of the compost heap to be delayed as physico-chemical properties of the compost heap may not be conducive for the occurrence of the required biochemical reactions (Baldwin and Greenfield 2009).

In October 2011 composts from all 4 cooperatives were 4 months old. However, the compost heaps were of different heights and were made up of varying amounts and combinations of manure. Farmers considered compost heap shrinkage and release of gas as indicators that it has cooled down and had reached maturity. According to Ryckeboer et al. (2003), tools that measure levels of O_2, moisture and temperature are necessary when determining composting stages and compost maturity. The uMbumbulu Agri-Hub cooperatives did not have these tools and therefore approximated compost maturity.

Faecal coliform levels met the US EPA standard set at <1000/g for compost. However the faecal coliform and *E. coli* levels decreased between October and December 2011. This suggests that compost was not sufficiently mature and continued to mature over the 3 months analysed leading to reduced levels of the hygiene indicators as a result of heat inactivation (Ryckeboer et al. 2003).

The Administration of Compost

Compost was administered into the soil in one of three ways: It was spread either on the top of the plot after the planting of seedlings, mixed with the soil prior to planting or added into individual holes before the planting of the seed. It was noted that there was some ambiguity about the science of composting amongst respondents. A number of farmers were aware of the decomposition aspect of composting but were unable to differentiate between materials that are readily decomposable and those that are not. Furthermore, farmers appeared to have a limited understanding of temperature variations within the compost heap. Several respondents admitted to depositing the faeces of domestic animals on top of a maturing compost pile, this practice could lead to the transfer of pathogenic bacteria to the surface of the leafy vegetables during the addition of compost to the soil. According to Baldwin and Greenfield (2009), the middle of the pile can reach temperatures of 63°C which kills most non-endospore forming pathogens. Therefore, the faeces of domestic animals (including pets like dogs and cats) added on top of the pile will not be sufficiently impacted by these high temperatures thereby increasing the risk of possible contamination.

Respondents reported that composts containing manure from cattle attracted flies, pests and rodents including cockroaches and mice which led them to believe that compost may be a source of contamination as many flies and pests are vectors of disease. Respondents agreed that bacterial outbreaks would lead to customer loss as customers would lose trust and always question the hygienic quality of their vegetables.

The use of wet and dried manure (umquba)

Besides its use in the making of compost, the respondents revealed that the use of fresh and dried manure was common amongst untrained farmers. The fresh manure was either used wet and mixed directly with the soil prior to planting seeds or the manure was firstly dried for approximately 3 weeks forming *Umquba* before being incorporated into the soil. A total of 24.7% of respondents admitted to using wet fresh manure directly on the soil while 50.7% of the respondents made *Umquba* (Table 4.2). The use of wet manure can be particularly dangerous as bovine faeces has been identified as reservoir of pathogenic *E*. *coli* strains (Omisakin et al. 2003) which can cause foodborne diseases. Furthermore, the drying of manure may not be sufficient to completely eliminate pathogenic strains of *E*. *coli* such as STEC which has a low infectious dose (Hodges and Kimball 2005).

Hygienic quality of leafy vegetables

Laboratory analysis of vegetables

The MPN values for total and faecal coliforms fluctuated from the month of October to December 2011 but remained below 1/g for both lettuce and spinach. *E*. *coli* was not isolated from the leaf surface (Table 4.6 and 4.7).

Table 4.6: MPN per g of total and faecal coliforms as well as *E. coli* on the surface of Spinach for different farmer cooperatives for the months of October, November, and December 2011.

Source of Spinach	October 2011		November 2011		December 2011	
	MPN/g	95% confidence interval lower / upper limit*	MPN/g	95% confidence interval lower / upper limit	MPN/g	95% confidence interval lower / upper limit
Total coliforms						
Nungwane	0.50	0.11/1.81	1.10	0.39/2.95	1.40	0.55/3.41
Senzakahle	1.40	0.55/3.47	1.40	0.55/3.47	1.10	0.39/2.48
Siyazenzela	0.70	0.22/2.15	0.70	0.22/2.15	0.80	0.24/2.95
Jabulani	0.20	0.028/1.41	1.40	0.55/3.47	1.40	0.55/3.47
Faecal coliforms						
Nungwane	0.20	0.028/1.41	0.70	0.2/2.15	0.50	0.11/1.81
Senzakahle	0.70	0.22/2.15	0.70	0.2/2.15	0.50	0.11/1.81
Siyazenzela	0.20	0.028/1.41	0.20	0.03/1.41	n.d	-
Jabulani	n.d	-	0.40	0.1/1.81	n.d	-
E. coli						
Nungwane	n.d	-	n.d	-	n.d	-
Senzakahle	n.d	-	n.d	-	n.d	-
Siyazenzela	n.d	-	n.d	-	n.d	-
Jabulani	n.d	-	n.d	-	n.d	-

*95% confidence limits calculated according to Garthright and Blodgett (2003) n.d- not detected (limit of detection is <0.02/g)

Table 4.7: MPN per g of total and faecal coliforms as well as *E. coli* on the surface of Lettuce for different farmer cooperatives for the months of October, November, and December 2011.

Source of Lettuce	October 2011		November 2011		December 2011	
	MPN/g	95% confidence interval lower / upper limit*	MPN/g	95% confidence interval lower / upper limit	MPN/g	95% confidence interval lower / upper limit
Total coliforms						
Nungwane	0.50	0.11/1.81	0.20	0.028/1.41	0.50	0.11/1.81
Senzakahle	1.40	0.55/3.47	0.70	0.22/2.15	n.d	-
Siyazenzela	1.40	0.55/3.47	0.90	0.34/2.50	0.70	0.22/2.15
Jabulani	0.70	0.22/2.15	0.70	0.22/2.15	0.70	0.22/2.15
Faecal coliforms						
Nungwane	n.d	-	n.d	-	0.20	0.281/1.41
Senzakahle	0.40	0.1/1.62	0.20	0.028/1.41	n.d	-
Siyazenzela	0.70	0.22/2.15	0.79	0.22/2.15	0.20	0.028/1.41
Jabulani	n.d	-	0.2	0.028/1.41	0.40	0.10/1.62
E. coli						
Nungwane	n.d	-	n.d	-	n.d	-
Senzakahle	n.d	-	n.d	-	n.d	-
Siyazenzela	n.d	-	n.d	-	n.d	-
Jabulani	n.d	-	n.d	-	n.d	-

*95% confidence limits calculated according to Garthright and Blodgett (2003) n.d- not detected (limit of detection is <0.02/g)

Though microbiological quality of raw fruit and vegetables is not sufficiently covered by current South African legislation, the DOH (2002) recommends that raw fruits and vegetables should have total coliform levels not exceeding 200/g. The lettuce and spinach sampled (Tables 4.6 and 4.7) had total coliform levels <2/g, thereby meeting this requirement for the months of October, November and December 2011. In addition, no *E. coli* was detected during these months. Further to this, vegetables produced by the farmers were thoroughly rinsed with uMbumbulu municipal tap water at the Agri-Hub, this water was thought to meet all DWAF drinking water standards. The additional rinsing with uncontaminated tap water can improve the microbiological quality of the produce (Abadius et al. 2008; Koseki et al. 2004). Although this rinsing is important, it is important that measures that prevent contamination are employed at all stages of production as pathogen internalization may occur rendering rinsing with water ineffective (Deering et al. 2012).

According to DWAF (1996), water quality is considered as a determinant of the microbial quality of the final vegetable product (DWAF 1996). The use of uncontaminated irrigation water sources is indeed important as potential links between water quality and microbiological quality of produce have been suspected (Gemmell and Schmidt 2012). Farmers should be advised to irrigate produce close to the root area, this is because surface irrigation increases chances of contamination especially if irrigated with water of unknown microbiological quality (Frank et al. 2011). Composting techniques and hygiene practices are also known to influence the quality of the final product.

4.4 Conclusion

Based on the data for the selected bacterial hygiene indicators, the uMbumbulu Agri-Hub produces vegetables that are apparently safe to consume during the months of October, November and December of 2011. Microbiological analysis of water and vegetable was within South African standards. All four cooperatives met the US EPA compost standard for faecal coliforms during the months under study. However, the need for farmers to gain access to tools that can assist them in determining compost maturity was highlighted.

There are limited numbers of training courses that focus specifically on microbiological quality in the farming environment. Farmers require training on good hygiene practices throughout the farming supply chain.

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Chapter 5

Summary and Recommendations

A large number of barriers hinder small-scale farmers' access to organic produce markets. One of these barriers is the lack of understanding of quality standards which ultimately prevents the sale of organic vegetables in South African chain supermarkets. Complying with such standards is important, as they are mechanisms to prevent health related outbreaks and ensure that vegetables products meet customer specifications. The importance of training was highlighted, as farmers who received training were more likely to practice good personal and production hygiene. Furthermore, these farmers had a good understanding of critical areas in the production system that could introduce potential hazards, however, farmers had limited knowledge on how to detect, prevent and control these hazards. Small-scale organic farmers are challenged with capacitating themselves on such standards and legislation as they are considered a sustainable alternative to commercial farming especially with the worlds increasing population. Government in particular has a fundamental role of supporting small-scale farmers. These farmers have the potential of being reputable players and contributors to the South African economy. Thus, government needs to ensure that there are institutions whose sole mandate is to assist small-scale farmers interested in pursuing organic farming as a livehood. These institutions need to address certification issues, ensure farmer training and that farmers have access to farming essentials such as productive land and reliable water sources.

The mixed method approach integrating quantitative and qualitative methods was used to engage farmers and collect data. Questionnaires, key informant interviews and laboratory analysis were conducted to investigate farmer practices and vegetable microbiological quality. Samples of irrigation water, produce and compost were collected in the months of October, November and December. The laboratory samples were analysed using the MPN approach and questionnaire data using SPSS 21.

Laboratory results indicated that the tested irrigation water and vegetables produced were hygienically safe. However, education is required in issues surrounding composting as farmers had to often estimate its maturity. Also, farmers required clarification on the type of materials readily degraded and those that were not. Training and farmer experience were found to be valuable tools in the adoption of good farming practices.

5.1 Conclusions

All respondents produced a variety of vegetables. Respondents produced these vegetables primarily for their own consumption; the surplus was then sold to the community or Agri-Hub. The types of vegetables produced were commended, as these were vegetables normally found in supermarkets.

The irrigation water sources, manure and vegetables produced during the months of October, November and December satisfied microbiological standards. However, lack of knowledge on the importance of composting was a cause for concern as this could contribute to the use of immature compost. This highlighted the need of technological tools that assessed the composts' biochemical properties that indicate maturity. In addition, the hazards associated with the use of wet or dry manure were highlighted. The implementation of Good Agricultural Practices (GAP's) and Good Hygiene Practices (GHP's) in the farming practices was strongly recommended to avoid produce contamination.

Training was identified as one of the defining influences of farmer practices. The importance of farmer training was emphasized; trained farmers had knowledge of potential contaminants, composted manure and were hygienic in their practices. Gender had no influence on the farming practices, this indicated that women were as actively involved as their male counterparts. Relationships existed between levels of education and farming practices, this was in line to literature that suggests that farming practices improve with higher levels of education.

5.2 Policy implications

Consumers are critical about the composition and nutritional benefits of the foods they buy. Foods labelled 'organic' assure consumers that measures to minimize contact with chemicals and synthetic fertilizers were adopted. It is therefore important for DAFF to develop a programme of certification that will allow for organic certification that is efficient, standardized and affordable. The department should also have capacity building programmes training farmers on all the criteria of certification.

This research has shown the importance and effectiveness of training programmes in minimising possible contamination in the organic farming environment. It is important that certification programmes recognise this and are linked with initiatives that train farmers in an effort to improve compliance of farmers' irrigation water, produce, compost and soil to the stipulated South African standards.

Mentorship programmes may be beneficial. This would involve the collaboration of skilled and unskilled organic produces. This would facilitate the flow of valuable information and discussion of best practices. Collaborations with supermarkets would facilitate in the fast tracking of economical development.

5.3 Recommendations on improvement of study

The Agri-Hub experiences highest sales in October, November and December due to more favourable weather conditions. Microbiological data collected during this time is important because the vegetables would reach a larger consumer base. However, data collected over a longer period of time would have portrayed trends and their possible causes clearer.

5.4 Further research

Small-scale farming is thought to have a positive contribution to the state of food security. However, research focusing on the contribution of South African small-scale farming to food security is limited. Studies documenting the impact of small-scale farming to food security are required.

Appendix

Appendix A: Questionnaire (English)

Section 1- Demographics

1.1 Gender

Gender	X
Male	
Female	

1.2 Age

Age	X
a. 20<	
b. 21-39	
c. >40	

1.3 Level of education

Level	X
a. Grade 7<	
b. Grade 8- Grade 12	
c. >Grade 12	
d. No formal education	

1.4 Sources of income: Tick all that apply

Source	Yes	No
a. Remittance		
b. Farming		
c. Social Grant		
d. Pension		
e. Salaried Job/Wages		
f. Other		

1.5 How much do you make from organic farming weekly during harvest time?

Amount (ZAR)	X
a. 0-250	
b. 251-500	
c. 501-1000	
d. >1001	

Section 2- Sub problem 1

Which vegetables are produced?

2.1 Why do you practice organic farming? Tick all that apply

Reason	Yes	No
a. Market demand of organic produce		
b. Cost effective		
c. Its gentle on the environment		
d. To ensure food security		
e. Other		

2.2 Which vegetables do you plant?

Vegetable	Yes	No	Vegetable	Yes	No
a. Carrot			f. Beetroot		
b. Green beans			g. Onion		
c. Potato			h. Lettuce		
d. Spinach			i. Cabbage		
e. Tomato			j. Swiss Chard		

Why do you plant these vegetables?

____

2.3 Who do you mainly supply?

2.4 Do you use the products yourself? Y / N

2.5 Do you always have a surplus to sell? Y / N

<u>Section 3- Sub problem 2</u>

What is the hygiene quality and safety of the salad vegetables?

3.1 Do you use animal manure in your farming activities? Y / N

3.2 Which type of waste is used? Tick all that apply

	Animals	**Yes**	**No**
a.	Chicken		
b.	Sheep		
c.	Cow		
d.	Other		

3.3 Where do you get it from?

3.4 Why is this type of waste used?

3.5 How do you prepare the animal manure? Please explain.

____

3.6 How is this manure/compost used in the plot? Please explain

____

3.7 Is the quantity of the manure/ compost used measured in any way? Y / N

If yes, how?

____

3.8 What is the source of irrigation water?

Source	**Yes**	**No**
a. Tap water		
b. Tank water		
c. River/borehole/stream/wetland (natural water sources)		
d. Other		

3.9 Is the water used for irrigation treated? Please tick most relevant answer

Process	**X**
a. Yes, it is treated before watering plants	
b. No, it is applied directly to plants without treatment	
c. Other	

3.10 In the case of (a) how is this water treated?

3.11 Do you adhere to any of the following with regards to personal hygiene before going to the garden? Tick all that apply

Process	Yes	No
a. Wash your hands and gum boots		
b. Wash all equipment required		
c. Go to the garden as you are		
d. Other		

3.12When harvesting, are there vegetables that are bruised or damaged? Y / N

3.13What do you do with the bruised or damaged vegetables?

Procedure	Yes	No
a. Sold to neighbours		
b. Sold to market but at a discount price		
c. Discarded		
d. Taken for personal use		

e. Other		

3.14Are vegetables rinsed before packaging for the market? Y / N

If yes, are they rinsed with the same water used for irrigation? Y / N

Section 4- Sub Problem 3

Which areas require capacity building in hygiene quality and safety?

4.1 Have you received any form of training in organic farming? Y / N

If yes, please name training programme. Tick all that apply

Programme	Yes	No
a. Composting		
b. Post-harvest protocol		
c. Water quality		
d. Types of sustainable agriculture		
e. Good personal hygiene practices		
f. Pest control		
g. Soil management		
h. Soil preparation		

i. Other		

4.2 Who provided the training?

Trainer	**Yes**	**No**
a. Government		
b. Private company		
c. NGO		
d. Other		

4.3 According to your knowledge, which of the following can be a source of bacterial contamination? Tick all that apply

Source	**Yes**	**No**
a. Water		
b. Soil		
c. Tools		
d. Compost		
e. Other		
f. Don't know		

4.4 Why are these possible sources of contamination?

4.5 In your opinion, which of the following practices can compromise the hygienic quality and safety of produce? Tick all that apply

Practice	Yes	No
a. Use of contaminated water		
b. Poor composting techniques		
c. Poor personal hygiene		
d. Contaminated soils		
e. Contaminated equipment		
f. Don't know		
g. Other		

4.6 What potential hazards may this have on the market? Tick all that apply

Potential Hazard	Yes	No
a. Bacterial outbreaks		
b. No hazards		
c. Lose trust of customers		
d. Other		
e. Don't know		

4.7 Do you have any knowledge of outbreaks/sickness linked to harvested fresh produce in your community? Y / N

4.8 According to your knowledge, is there enough awareness about produce quality and safety in your community? Y / N

If no, what do you think should be done to improve awareness?

____

4.9 What training related to hygienic safety of vegetables do you think you need? Please explain

____

Appendix B- Chi-square test (STATA 11)

Key
frequency
row percentage

Main income source	Age <40	Age >=40	Total
Remittances	2	3	5
	40.00	60.00	100.00
Farming	5	10	15
	33.33	66.67	100.00
Social grants	9	10	19
	47.37	52.63	100.00
Old age pension	0	21	21
	0.00	100.00	100.00
Wage	4	9	13
	30.77	69.23	100.00
Total	20	53	73
	27.40	72.60	100.00

Pearson chi2(4) = 12.4736 Pr = 0.014

Key
frequency
row percentage

Main income source	Gender Male	Gender Female	Total
Remittances	2	3	5
	40.00	60.00	100.00
Farming	8	7	15
	53.33	46.67	100.00
Social grants	3	16	19
	15.79	84.21	100.00
Old age pension	8	13	21
	38.10	61.90	100.00
Wage	8	5	13
	61.54	38.46	100.00
Total	29	44	73
	39.73	60.27	100.00

Pearson chi2(4) = 8.3130 Pr = 0.0

Key
frequency
row percentage

Main income source	Education level: No educat	Primary	Secondary	Total
Remittances	3	2	0	5
	60.00	40.00	0.00	100.00
Farming	7	6	2	15
	46.67	40.00	13.33	100.00
Social grants	4	11	4	19
	21.05	57.89	21.05	100.00
Old age pension	11	6	4	21
	52.38	28.57	19.05	100.00
Wage	2	4	7	13
	15.38	30.77	53.85	100.00
Total	27	29	17	73
	36.99	39.73	23.29	100.00

Pearson chi2(8) = 15.1038 Pr = 0.057

Key
frequency
row percentage

Main income source	Age: <40	>=40	Total
Remittances	2	3	5
	40.00	60.00	100.00
Farming	5	10	15
	33.33	66.67	100.00
Social grants	9	10	19
	47.37	52.63	100.00
Old age pension	0	21	21
	0.00	100.00	100.00
Wage	4	9	13
	30.77	69.23	100.00
Total	20	53	73
	27.40	72.60	100.00

Pearson chi2(4) = 12.4736 Pr = 0.014