PHYSICAL AND SENSORY QUALITY, AND β-CAROTENE CONTENT OF SOLAR DRIED VEGETABLES AND REHYDRATED MIXTURES COMPARABLE TO SWAZI VEGETABLE STEWS

By

PHUMZILE MDZINISO

Bachelor of Science

University of Swaziland

Faculty of Agriculture

Swaziland

1998

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 2002

PHYSICAL AND SENSORY QUALITY, AND
β-CAROTENE CONTENT OF SOLAR DRIED
VEGETABLES AND REHYDRATED
MIXTURES COMPARABLE TO
SWAZI VEGETABLE STEWS

Thesis Approved:

Margaret Hinds
Thesis Advisor

Gail Gates

Danielle Bellmer

Barbara J Brown

Timothy J. Pettibone
Dean of the Graduate College

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and appreciation to my advisor, Dr. Margaret J. Hinds for your guidance and advice, understanding and caring while facilitating this research, which has been a tremendous learning process for me. I respect your knowledge and patience and appreciate the time and energy you put into this work. I know that my research had challenges that have often deprived you of some sleep as you 'turned in your bed' in the early morning hours of the night. I can never be able to thank you enough for your assistance.

My deepest thanks and appreciation also go to my committee members for their willingness to help whenever requested and for showing interest in my work. I will always be grateful to you, Dr. Gail Gates, Dr. Danielle Bellmer, and Dr. Barbara Brown for giving me the motivation and making me feel what I was doing was an important piece of work.

I would like also to thank the following people who also contributed so much to the success of my thesis in different ways:

- Wayne R. Kiner for designing and constructing my solar drier.
- David Moe, who gave me access to the steam blancher and showed me how to operate it.
- Dr. Mark Payton for his advice and time spent on the statistical analysis of my data.

- Dr Tim Bowser for giving me his humidity meter to use during my research.
- Darren Scott, Food Scientist/Sensory, who assisted me during the sensory evaluation.
- The African students who volunteered to participate in the sensory evaluation.
- Vuvu Dlamini and her mom, Sibo Mtshali-Dlamini, who assisted me with steam-blanching process and provided transport whenever I needed it.
- The Nutritional Science Department staff who have showed interest in my research and provided support when I was in a stressful condition.
- My colleagues who always gave me support and encouragement every time the weather became unfavorable.
- Cindy Conway who spent a lot of time and patience typing and formatting my thesis.

I very much thank my parents for giving me the foundation of my educational life and all my family members for their continued support..

Most of all I want to thank my husband, Jabulani Mdziniso, for being there for me all the time. I appreciate your caring, comforting, support and encouragement extended to me, at all times, and when I needed it the most.

Finally, I wish to thank the W. W. Kellogg Foundation, Africa Study Grants Program, for giving me the opportunity to study in the United States by funding my stay here and my research. I appreciate the encouragement and caring provided to me by AED Africa Program staff in Washington, DC during my stay in the United States.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

Background 1
Justification 4
Limitations 4
Definition of Terms and Abbreviations 5
Research Questions 5
Hypothesis 6
Objectives of the Study 7
Aim 7
Objectives 8

II. REVIEW OF LITERATURE 10

Vitamin A. Overview 10
Functions of Vitamin A 11
Vitamin A Deficiency 12
Definition and Methods of Drying 13
Open-Air Sun Drying 13
Solar Drying 15
Oven Drying 17
Dehydrator Drying 17
Pretreatment and Its Effects on Dried Vegetables 17
Product Quality 19
Vegetable Dimensions and Solar Drier Tray Load 22
Rehydration 22
Sensory Evaluation 24

III. THE EFFECTS OF SOLAR DRYING ON PHYSICAL QUALITY AND BETA-CAROTENE CONTENT OF GREEN LEAFY AND YELLOW SUCCULENT VEGETABLES 27

ABSTRACT 28
INTRODUCTION 29

Chapter Page

MATERIALS AND METHODS 31

Experimental Design 31
Source and Sample Preparation 32
Determination of Blanching Time and Treatment 33
Drying Vegetables 33
Moisture Determination 34
Color 35
Texture Analysis 36
Water Activity 36
Beta-Carotene Analysis 37
Data Analysis 37

RESULTS AND DISCUSSION 38

Effects of Vegetable Type on the Properties of Fresh Vegetables 38
Effects of Vegetable Type on the Properties of Dehydrated Vegetables 39
Effects of Vegetable Dimensions on the Properties of Dehydrated Vegetables 42
Effects of Solar Drier Load on the Properties of Dehydrated Vegetables 43
Interaction Effects of Independent Variables 43
Effects of Vegetable Dimensions and Solar Drier Load on Treatments of Individual Vegetables 43
Water Activity 44
Rate of Dehydration 48
Beta-Carotene 50
Total Carotenoids 51
Changes in Properties Due to Dehydration of Vegetables 52
Equilibrium Moisture Content 55
Conclusion 55
Recommendations 57
Future Research 58

IV. SENSORY QUALITY OF SWAZI VEGETABLE STEWS PREPARED FROM REHYDRATED SOLAR DRIED VEGETABLES 59

ABSTRACT 60
INTRODUCTION 61
MATERIALS AND METHODS 63

Selection of Samples 63
Rehydration Procedures 64
Texture Analysis 64
Preparation of Stews 65

Chapter Page

Sensory Evaluation 67
Data Analysis 69
Results and Discussion 69
Color 70
Appearance 72
Flavor 72
Texture 72
Influence of Demographic Variables 73
Consumption Interest 73
Beta-Carotene Content in the Stews 74
Conclusion 75
Recommendations 75
Future Research 76

REFERENCES 77

APPENDICES 82

APPENDIX 1—PRE-PROCESSING OPERATIONS 83

APPENDIX 2—PEROXIDASE TEST 85

APPENDIX 3—TABULATED RESULTS 87

APPENDIX 4—SOLAR DEHYDRATION 91

APPENDIX 5—SENSORY EVALUATION 99

APPENDIX 6—TEXTURE PROFILE GRAPHS 108

APPENDIX 7—IRB FORM 112

LIST OF TABLES

Table Page

Chapter III

1 Treatments Applied to Carrots, Sweet Potato and Collard Greens During Dehydration....32

2 Effects of Vegetable Type on Properties of Fresh Carrots, Sweet Potato, and Collard Greens....39

3 Influence of Vegetable Type, Vegetable Dimension and Solar Drier Load on the Dependent Variables (Results of Proc Mixed)....41

4a LSMeans Effects of Vegetable Type on Properties of Dehydrated Vegetables....42

4b LSMeans Effects of Vegetable Dimensions and Solar Drier Load and on Properties of Dehydrated Vegetables....43

5 Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Carrots....45

6 Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Sweet Potato....46

7 Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Collard Greens....47

8 Changes in Color and Texture in Carrots, Sweet Potato, and Collard Greens Due to Solar Dehydration....53

9 Percent Loss in Beta-Carotene Due to Solar Dehydration of Carrots, Sweet Potato, and Collard Greens....54

Chapter IV

1 Beta-Carotene Content and Properties of Dried Vegetables Upon Rehydration....66

Table Page

2 Treatment and Ratios of Collard Greens and Carrots Used to Prepare Stews.......67

3 Frequency of Consumption Intent for the Six Stews...70

4 Overall Mean Scores for Sensory Evaluation of Vegetable Stews by Male and Female Panelists...71

5 Beta-Carotene Content in the Formulated Stews...74

APPENDIX 1

1 Blanching time Established from Results of Peroxidase Test for Collard Greens, Carrots and Sweet Potatoes...84

APPENDIX 3

1 Dehydration Rate, Drying Time and Product Yield for Replication 1 88

2 Dehydration Rate, Drying Time and Product Yield for Replication 2 89

3 Moisture β-Carotene Content in Fresh and Dehydrated Vegetables 90

LIST OF FIGURES

Figure Page

CHAPTER I

1 Flow Chart for Dehydration, Rehydration and Sensory Evaluation of Vegetables 9

CHAPTER III

1 Effects of Vegetable Type on Texture of Dehydrated Vegetables 40

2 Effects of Solar Drier Load on Water Activity 48

3 Effects of Vegetable Type and Solar Drier Load on Rate of Dehydration 48

4 Effects of Vegetable Type on Beta-Carotene of Dehydrated Carrots, Sweet Potatoes, and Collard Greens 51

APPENDIX 4

1 Drying Curves for 3mm and 5mm Thick Carrots with $460g/m^2$ and $715g/m^2$ Loads 94

2 Drying Curves for 3mm and 5mm Thick Sweet Potato with $460g/m^2$ and $715g/m^2$ Loads 95

3 Drying Curves for Collard Greens, 2cm and 3cm Thickness and $360g/m^2$ and $465g/m^2$ Loads 96

CHAPTER I

INTRODUCTION

Background

Swaziland is blessed with a variety of edible leafy vegetables. Some grow spontaneously as weeds during the summer season when there is plenty rainfall, and some are grown in communal vegetable gardens for consumption and income-generation. They are the most reliable, cheap and affordable food, especially to low-income families. Stews made from green leafy vegetables and groundnut sauces are the most common food that is eaten with the staple food, thick maize porridge.

Despite the availability and easy access to these vegetables, vitamin A deficiency in the diet remains a major health concern in Swaziland, especially among children of 6 - 71 months old. This is according to the vitamin A study that was conducted in the country in 1995 (National Nutrition Council, 1997). The study showed that 46% of children had marginal Vitamin A status (serum Vitamin A <20ug/dl), and 7% had vitamin A deficiency (serum Vitamin A <10ug/dl). The study further revealed that people from rural areas were the most affected. Unfortunately, about 70% of the population lives in these areas (Swaziland Annual Statistical Bulletin, 1995, Swaziland Government).

Vitamin A deficiency was also attributed to seasonality of the vegetables and lack of appropriate technology to enhance production, processing and preservation of the vegetables. The random air sun-drying methods presently used in Swaziland, give rise to dried leaves that are poor in quality, are often mixed with extraneous materials, and are not generally acceptable to consumers when they are rehydrated in the stews. Solar drying is thus being investigated as an alternative method to improve the physical and aesthetic quality of the dried vegetable materials. This is also to ensure adequate supply of vitamin A year round. Although vitamin A is stored in the liver, the ingested amounts during the season of availability may not be enough to maintain adequate vitamin A status throughout the year.

From a follow-up study that was conducted in 1999, it was found that most of the available indigenous green leafy vegetables in Swaziland were potential sources of vitamin A (Swaziland Nutrition News, 1999, Nutrition Council). However Allen and Gillespie (2001), stated that green leafy vegetables generally, do not provide adequate levels of ß-carotene because they have a relatively low content of ß–carotene, and the provitamin A from these green leafy vegetables is also poorly absorbed compared to that from the yellow vegetables. Yellow succulent vegetables like carrots, sweet potato and intense yellow pumpkin contain higher levels of beta-carotene than do green leafy vegetables (Allen and Gillespie, 2001). These yellow vegetables are presently not dried in Swaziland, nor eaten in the traditional vegetable stews.

The amount of beta-carotene concentrated after drying is different for different vegetables. Some vegetables, like amaranth (a green leafy vegetable), have been found to lose more beta-carotene than others. Therefore, blending vegetables that are low in beta-carotene and those higher in beta-carotene could bring about a balance of the beta-carotene (Lakshmi and Vimala, 2000). Dried carrots and yellow-fleshed sweet potatoes have been found to contain more beta-carotene than dried green leafy vegetables (Rock *et al.*, 1998). Thus, the higher beta-carotene vegetables would compensate for the lesser amount of beta-carotene in the leafy vegetables. Hence, vegetable stew mixtures containing dried green and yellow vegetables could be formulated to increase the ß-carotene content in the Swazi diets. The formulated mixtures for stew preparation could contain appropriate ratios of the green and yellow vegetables to provide the Daily Recommended Allowance of ß-carotene to the Swazi meal. This would agree with Ruel's (2001) description of food-to-food fortification, in her review of popular approaches that could be used to address vitamin A deficiency in developing countries. She described food-to-food fortification as a strategy used to incorporate micronutrient dense foods into preparation of traditional dishes that are poor in micronutrients.

The purpose of this study is to improve quality attributes and bioavailability of ß-carotene in Swazi meal stews traditionally prepared from dried leafy vegetables. The study involves (1) developing solar drying protocols for green leafy and yellow succulent vegetables; (2) testing beta-carotene content of solar dried green and yellow vegetables, (3) formulating stew mixtures containing various ratios of dried green to yellow vegetables, and (4) determining the acceptability of the high ß-carotene vegetable stews by African consumers (Figure 1).

Justification

Since increasing the amount of bioavailable micronutrients in plant foods is a challenge that is particularly important for developing countries, this study will determine possibilities for increasing the content and bioavailability of vitamin A in Swazi stews, in order to increase food security and reduce vitamin A deficiency among the rural young children. This population is the most affected in the Swaziland. The results of the study will be most useful to the staff of the Ministry of Agriculture and Cooperatives and Non-governmental Organizations that work directly with communities because they are facilitators for food production, processing and preservation extension services. The results will also be used to transfer technology for drying other types of locally available green leafy and succulent vegetables to Swaziland.

Limitations

Weather conditions in Stillwater, Oklahoma during late spring-summer 2002 were somewhat atypical, and frequently not favorable for the drying process. There was too much rain causing high humidity that prolonged dehydration, and sometimes vegetables became spoiled. As a result, the proposed number of three process replications could not be accomplished by the end of summer.

Vegetables were not harvested from the local farms shortly before processing but were purchased from Albertson's and Food Outlet Supermarkets, which led to a variation in the quality of the vegetables. Most vegetables had been transported from other states. Therefore, the criteria for selection (fresh, young and tender) were not easily met.

Moreover, nutrients may have been lost during transportation. Hence, the results of the study could be influenced.

Definition of Terms and Abbreviations

β-Carotene: a precursor of vitamin A that is naturally found in a variety of fruits and vegetables with yellow/orange colors

Bioavailability: the proportion of the micronutrients in food that is absorbed and utilized by the body for normal physiological functions

VAD: Vitamin A Deficiency

Flavor: a complex group of sensations including taste, olfactory and other chemical sensations.

Aroma: the odor of food as perceived by the nose

Texture: characteristic of food product as perceived by visual, tactile or auditory senses

Panelist: a person who uses her/his senses to evaluate food characteristics

Solar drying: method of drying in an enclosed chamber that functions as a blackbody. The chamber converts the absorbed sunlight into heat, and facilitates contact of the warm air with the materials (e.g. vegetables) in the chamber.

Research Questions

1. What is the effect of vegetable type on rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables?
2. What is the effect of vegetable type on β-carotene content of solar dried vegetables?

3. What is the effect of thickness of pre-dried vegetables on rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables?
4. What is the effect of thickness of pre-dried vegetables on β-carotene content of solar dried vegetables?
5. What is the effect of load (packing depth) in the solar drier on rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables?
6. What is the effect of load (packing depth) in the solar drier on β-carotene content of solar dried vegetables?
7. What is the effect of vegetable type on sensory quality of stews containing mixtures of rehydrated solar dried vegetables?
8. What is the effect of thickness of pre-dried vegetables and / or solar drier load (packing depth) on sensory quality of stews containing mixtures of rehydrated solar dried vegetables?
9. What is the effect of the ratio of yellow to green solar dried vegetables on the acceptability of Swazi stews compared to the acceptability of traditional stews prepared from fresh green vegetables only.

Hypothesis

1. There will be no difference between vegetable type in rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables.
2. There will be no difference between vegetable type in β-carotene content of solar dried vegetables.

3. There will be no difference in rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables due to thickness of vegetables.
4. There will be no difference in β-carotene content of solar dried vegetables due to thickness of vegetables.
5. There will be no difference in rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables due to load (packing depth) in solar drier.
6. There will be no difference in β -carotene content of solar dried vegetables due to load (packing depth) in the solar drier.
7. There will be no difference between vegetable type in sensory quality of stews containing mixtures of rehydrated solar dried vegetables.
8. There will be no difference due to thickness of pre-dried vegetables or solar drier load (packing depth) on sensory quality of stews containing mixtures of rehydrated solar dried vegetables.
9. There will be no difference in acceptability of Swazi stews containing mixtures of solar dried green and yellow vegetables compared with traditional stews prepared from fresh green vegetables only.

Objectives of the Study

Aim. To improve the quality attributes and bioavailability of ß-carotene in Swazi vegetable stews traditionally prepared from dried leafy vegetables.

Objectives.

1. To evaluate the effect of vegetable type on rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables.
2. To evaluate the effect of vegetable type on β-carotene content of solar dried vegetables.
3. To evaluate the effect of thickness of pre-dried vegetables on rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables.
4. To evaluate the effect of thickness of pre-dried vegetables on β-carotene content of solar dried vegetables.
5. To evaluate the effect of load (packing depth) in the solar drier on rate of dehydration, color, texture, moisture content and water activity of solar dried vegetables.
6. To evaluate the effect of load (packing depth) in the solar drier on β-carotene content of solar dried vegetables.
7. To evaluate the effect of vegetable type on sensory quality of stews containing mixtures of rehydrated solar dried vegetables.
8. To evaluate the effect of thickness of pre-dried vegetables and / or solar drier load (packing depth) on sensory quality of stews containing mixtures of rehydrated solar dried vegetables.
9. To evaluate acceptability of Swazi stews containing composite mixtures of solar dried green and yellow succulent vegetables compared with traditional stews prepared from fresh green vegetables only.

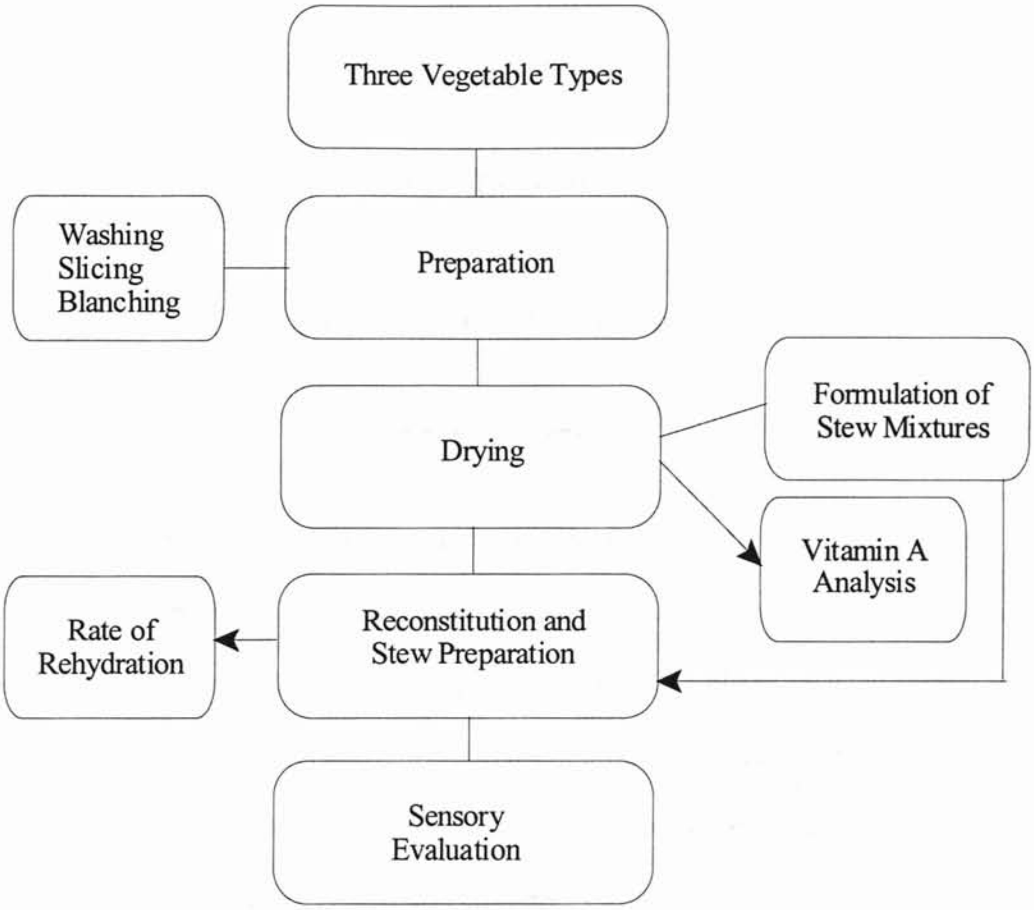


Figure 1

Flow Chart for Dehydration, Rehydration and Sensory Evaluation of Vegetables

CHAPTER II

REVIEW OF LITERATURE

Vitamin A Overview

Vitamin A is a fat-soluble vitamin that can be found in the body as retinol or retinyl esters. The major sources of vitamin A in the diet are preformed vitamin A and provitamin A carotenoids. Preformed vitamin A is found mainly in selected animal foods especially liver, dairy products and some fish like sardines, tuna and herring. It is readily absorbed in the intestines in the presence of fat and transported in the blood as vitamin A esters and is stored in the liver (Groff and Gropper, 1999).

There are more than 600 carotenoids of which three are the precursors of vitamin A (beta-carotene, alpha-carotene and beta-cryptoxanthin). Beta–carotene is the most common provitamin A carotenoid that is found naturally in a variety of fruits and vegetables with yellow-orange colors, e.g., carrots, papaya, sweet potato, and pumpkin. Green vegetables also provide large amounts of vitamin A in the form of provitamin A carotenoids even though the bright colors cannot be seen as they are masked by chlorophyll. Unfortunately, most of these fruit and vegetable sources of vitamin A are highly seasonal, a situation that may cause low-income populations to suffer from chronic, mild to moderate vitamin A deficiency or severe seasonal deficiencies (Rahman and Perera, 1999, Booth *et al.*, 1992). Fruits and vegetables are a major source of vitamin A in the diets of a large proportion of the world's population, especially Africa and Asia. (IVACG, 1999).

Provitamin A carotenoids are not efficiently absorbed because their absorption depends on many factors including food preparation practices, presence of dietary fat, presence of other food components that inhibit their absorption, parasitic infection, and quantity ingested (Nalubola and Nestel, 1999, Booth *et al.*, 1992). However, carotenoid-containing foods are generally able to meet the minimum vitamin A requirement of both children and adults as long as they are prepared properly and eaten in sufficient quantities.

Recent studies have found that the bioconversion of provitamin A in dark green leafy vegetables is less than a quarter of that previously thought. However, the yellow-orange fruits and vegetables still contain large amounts of well-absorbed carotenoids (Allen and Gillespie, 2001). Therefore, strategies to maintain good vitamin A status should include the promotion of suitable vegetables and fruits, and appropriate processing and storage of these plant products in order to retain more vitamins and minerals and extend the time when they will be available.

Functions of Vitamin A

The most widely known function of vitamin A is vision. The World Health Organization (WHO) has estimated that 250 million preschool-age children have a sub-clinically deficiency and 3 million have clinical xerophthalmia. Xerophthalmia is a progressive blindness that is caused by vitamin A deficiency. Although blindness in Africa may be caused by other factors, millions of people are affected by blindness because of vitamin A deficiency. Vitamin A influences the functions of the immune system, especially the T–lymphocyte function and the antibody response to viral, parasitic and bacterial infections. Vitamin A deficiency results in impaired antibody formation. Vitamin A is important for growth and cellular differentiation and has been shown to stimulate epithelial cells. It is required for bone development and maintenance (Ncube *et al.*, 2001; Semba *et al.*, 1998; Tomkins, 1987).

Vitamin A Deficiency

Ritu and Nestel (1999) described vitamin A deficiency as a significant public health problem causing about 70% deaths per year in children who are blind. This has not only affected children, but also pregnant women who are at higher risk of developing vitamin A deficiency because of the increased demand by the fetus. Vitamin A deficiency during pregnancy in Human Immunodeficiency Virus (HIV)-infected women, has been associated with increased mother-to-child transmission of HIV and higher rates of infant mortality (Semba *et al.*, 1998). Besides preschool children and pregnant mothers, lactating mothers are the most affected because their vitamin A requirement is increased during lactation and exceeds that in pregnancy because they need to replace the amount transferred to the infant through breast milk (Ncube *et al.*, 2001).

Vitamin A deficiency is also associated with diseases that cause morbidity and mortality in developing countries (Ritu and Nestel, 1999, Semba *et al.*, 1998). Such diseases include diarrhea, measles, acute respiratory infections, parasitic infections and recently, HIV. These conditions have been said to be responsible for the loss of more than 30% of disability-adjusted life years in developing countries.

Definition and Methods of Drying

Rahma and Perera (1999) defined drying as a reduction of moisture content from an initial value to some acceptable final value. The purpose of drying is to reduce water activity so that microbial growth and chemical deteriorative reactions are retarded. Water activity is the availability of water for deteriorative and spoilage reactions in food. A decrease in water activity slows chemical reactions and microbial growth until most reactions are inhibited. Optimum water activity for food differs among specific foods. For dried vegetables, a water activity of 0.6 is recommended in order to prevent microbial proliferation (VanGarde and Woodburn, 1994, McWilliams 2001). Therefore, water activity of a food determines whether it would be susceptible to spoilage by microorganisms or whether it would have a long shelf life. Dried vegetables need to have low enough water activity to ensure their shelf stability. Drying also allows for easy storage of food in limited space and gives variety to the diet. The most commonly used methods of drying include: open-air sun drying, solar drying, oven drying and dehydrator drying.

Open-Air Sun Drying

This is the most common method used to preserve agricultural products in most tropical and subtropical developing countries, where the produce are spread on mats and trays to be dried. Severe losses of nutrients have been found to occur during sun drying as a result of the direct sunlight, unfavorable environmental conditions (e.g., wind, dew, dust), rodents, birds and microorganisms (Mosha *et al.*, 1997; Badifu *et al.,* 1995). This was also confirmed by Dignos *et al.* (1992) when they evaluated the effects of processing on beta-carotene content in sweet potatoes. They found an average loss of 38% beta-carotene; almost double the value of oven drying that resulted in 20% loss of beta-carotene. Lyimo *et al.* (1990) looked at the effects of processing, preservation and storage on nutrient content of locally used vegetables in Tanzania and found that sun drying caused the highest loses of carotenes in all vegetables studied, and higher than 50% loss in some. This shows that there is need to minimize such losses in order to improve the vitamin A status in the populations that live on plant foods for their sources of vitamin A. Drying under the shade could reduce the losses since beta-carotene is sensitive to direct sunlight. Researchers have reported that open-air sun dried vegetables retained less beta-carotene than oven dried vegetables, (Badifu *et al.*, 1995; Dignos *et al.*, 1992; Yadav and Sehgal, 1995), shade dried (Mosha *et al.*, 1997; Lymo *et al.*, 1991), and solar dried vegetables (Lakshmi and Vimala, 2000; Maeda and Salunkhe, 1981; Negi and Roy, 2000; Gomez, 1981).

Sun drying method is highly dependent on weather conditions, relative humidity and temperature. Even though it is less costly than all other drying methods, it takes more time to dry the product. Dignos *et al.* (1992) found that sun-drying took 2-3 days, thus high losses of provitamin A were encountered due to lengthy direct exposure to light and air. Lakshmi and Vimala (2000) also found that sun-drying took 5 to 10 times longer time to bring moisture content to almost the same level when compared with solar drying. The quality of sun-dried food is reduced. Discoloration of products also occurs as a result of either insufficient drying or over drying. According to Esper and Muhlbauer (1998), sun dried foods do not fulfill the international quality standards and cannot be sold successfully. The poor quality does not only affect the market but also nutritional status. In most developing countries where vegetables are plentiful and sun drying is practiced, malnutrition still persists because of the poor quality of the preserved foods that are consumed.

Solar Drying

Solar drying is different from sun drying. A solar drier consists of an enclosed chamber that function as a blackbody, which absorbs the sunlight and converts it into heat. The surrounding air is warmed. As the warm air rises, it passes through the sieves on which the vegetables are placed, and dries them. Cooler air is sucked through the bottom of the collector and the process begins again (ULOG, 1998). Solar drying is one of the popular methods of drying that have been promoted in recent years in many countries like Tanzania, Haiti, Mali, Senegal, and the Dominican Republic (Ruel, 2001). It is an alternative to the traditional sun drying method that results in significant losses of beta-carotene. In solar drying, food is dried under the shade, high air temperature and low humidity in order to hasten drying rate and reduce the final moisture content. When a study on the retention of ascorbic acid and total carotene in solar dried vegetables was conducted, Maeda and Salunkhe (1981) found that the highest amount of the provitamin was retained when the solar drier was placed under the shade. Minimum retention of provitamins was observed where the solar drier was placed in direct sunlight. Since carotene is sensitive to direct light exposure, solar dehydration under sunlight may lead to significant destruction of the provitamin. Therefore minimizing light exposure through shade provision can improve the carotene retention percentage.

Solar drying increases the micronutrient concentration in the dried products and enables the products to be stored longer. The rate of β-carotene retention varies with produce type, but the retention range for solar dried vegetables was found to be from 50 to 80% (Ruel, 2001). The advantage of solar drying is that it takes a shorter time to dry a product because the sun's rays are concentrated in the drier. Due to the intense heat that circulates in the solar drier, the rate of dehydration is increased. Lakshmi and Vimala (2000) found that with lesser dehydration ratio, the yield was more in the solar drier because of fewer losses of solids as compared with sun drying. Solar driers provide protection from adverse environmental conditions such as rain, wind, frost, rodents, birds and insects. Contamination by microorganisms is reduced, and considerable increase of shelf life is facilitated. According to Esper and Muhlbauer (1998), when compared with sun drying, products dried in the appropriate solar drier led to a reduction of drying time by up to 50% and a significant improvement in quality in terms of color, texture and taste. Solar drying is considered an effective means of preservation suitable for small farmers in the rural areas, where solar energy may be the only reliable and available source of energy. Esper and Muhlbauer (1998) predicted that solar energy would be the future source of energy due to the population food imbalance and shortage of fossil fuels.

Other studies have shown that, in order to address food security, post harvest losses, increased product quality and improvement of the existing methods of preservation, should be enhanced (Ruel and Levin, 2000). Methods of preservation play a great role in nutrient retention. This was evident from a study conducted in Ghana that observed dietary patterns in rural areas, and the relevance for vitamin A consumption. Even though the areas had a variety of vitamin A rich foods available with few cultural beliefs to hinder adequate consumption, vitamin A deficiency was still a problem. That condition was attributed to the traditional preservation techniques, cooking and storage methods used. Seasonality of the vegetables was also found to hinder adequate consumption of vitamin A (Hudelson *et al.*, 1999). Hence, with improved preservation techniques the available fruits and vegetables could be preserved during the time of abundance to extend the time of availability and benefit the population.

Oven Drying

This method is suitable for drying small quantities of product at a time. Thus it can be time consuming and costly due to high-energy requirements. It also requires attention and time because the product needs to be shifted and rotated occasionally for even drying. Otherwise, the product may become scorched and that would result in reduced product quality (Esper and Muhlbauer, 1998).

Dehydrator Drying

This method is the most reliable method of drying because the temperature is controlled by a thermostat and air circulation is also controlled (Esper and Muhlbauer, 1998). For that reason, food quality is improved but it can be costly and may be out of reach for many low-income people.

Pretreatment and Its Effects on Dried Vegetables

Blanching is a primary step in processing vegetables, especially for drying. The main function of blanching is to inactivate the naturally occurring enzymes found in food.

The enzymes are responsible for discoloring or browning foods, reducing nutritional quality, flavor and texture of food (VanGarde and Woodburn, 1994). Blanching is also essential for its color fixing effect, and this increases acceptability of the product.

The color of green and yellow-orange vegetables is due to chlorophyll and carotenoids, respectively. Premavali *et al.* (2001) reported that total chlorophylls decreased during blanching and dehydration, but loss of color in terms of carotenoids and chlorophyll was different from vegetable to vegetable. In their study, losses of chlorophyll/color during dehydration ranged from 4.4 to 48%. Total carotenoid retention on dehydration ranged from 36.1 to 94%.

Even though Rahman and Perera (1999) found that blanching enhanced the color and acceptability of the food, Negi and Roy (2000) stated that blanching led to nutrient degradation especially of vitamin A, loss of color, flavor and texture. Like Rahman and Perera (1999), other researchers also reported that blanching improved the color and acceptability of the leaves especially if done for the shortest time of enzyme inactivation (Yadav and Sehgal 1995; Onayemi and Badifu, 1987). From the different reports, it is clear that the most important blanch factors that need close monitoring are time and temperature. The process of blanching could improve the color, flavor, texture and nutrient quality (Mosha *et al.,* 1997) of dried vegetables if done under optimum conditions. Contradictory reports have been made on whether blanching decreases the concentration of total carotenoids. However, Premavalli *et al.* (2001) concluded that the stability of color and vitamins is different depending on the leafy vegetables being processed, as evidenced by the results obtained from the seven varieties of green leafy vegetables processed in their study.

Quintero *et al.* (1992) studied the effect of low-temperature long-time blanching on the texture of dehydrated carrots after rehydration and reported that blanch temperature and blanch time had a significant effect on firmness. Firmness of the carrots increased with blanching time. Blanching carrots at 65° C and 45 min. increased the firmness of the carrots. However, they found little effect on rehydration ratios. Onayemi and Badifu (1987) investigated the effects of blanching and drying methods on the nutritional and sensory quality of green leafy vegetables. Dried vegetables were rehydrated in water, at room temperature and color was measured. They found that water blanching and sun drying resulted in greater reduction of carotene levels than vegetables that were steam- blanched and dried in a cabinet drier.

Mazza (1983) reported that blanching had a more significant influence on the rate of moisture movement during dehydration of carrots because of the changes in physical properties of the tissues, that is the destruction of the cell membrane by heat and loss of soluble solids. Leaching of soluble solids from carrots before dehydration increased loss of carotenoid pigments during dehydration, which in turn reduced the storage stability (Balochi *et al.*, 1977). Optimal blanching conditions for a particular vegetable may be established by use of the Peroxidase Test as a confirmatory test (Luh and Woodroof, 1975).

Product Quality

For proper and safe preservation, selection of a high quality product is important. This involves appropriate handling and harvesting practices before treatment. The maturity of the produce before harvesting is important because it determines how much moisture is in the product. Vegetables should be fresh, young and tender. Over-mature products are not recommended because they do not score well during sensory evaluation. Quality characteristics are affected by moisture content of produce after harvesting and water activity.

Other factors that affect quality are relative humidity and rate of dehydration. The velocity of air passing through the material being dried and the relative humidity are the most important factors that control the rate of dehydration (Luh *et al.*, 1975). The rate of dehydration and final moisture content of the dehydrated vegetables will influence the quality of the rehydrated vegetables and ß-carotene content. Reducing thickness of the drying pieces of vegetables may shorten drying time. However the final vegetable size depends on the end use of the product because it should represent the consumer's requirement for that certain particle size and the need for rapid drying (Luh *et al.*, 1975). With high relative humidity, drying process is prolonged, and other quality properties like color and texture of the product may be compromised (Mosha *et al.*, 1997; Rahman and Perera, 1999).

Cai and Corke (2001) evaluated the extent of drying required for safe storage of pigment in amaranthus (a green leafy vegetable). They compared freeze-drying, oven and solar drying and found that with low temperatures, moisture decreased slowly and drying time was long or extended. As a result, degradation of pigments was fast because enzymes had higher activity under low temperature compared with high temperature and fast decrease of moisture. For high temperature (70–80C), they observed that enzymes were quickly inactivated and thus pigment degradation slowed down. However, elevated temperature can cause browning. During mild browning, only color will change but as browning furthers, flavor, nutrient content and rehydration capacity may be adversely affected.

Beta-carotene is sensitive to air, light and heat (Badifu *et al.,* 1995) such that provitamin A carotenoids are easily destroyed by exposure to light and during processing, heating and storage. Thus ß-carotene retention decreases with longer processing time and elevated temperatures. Reducing processing time by using high temperatures can improve retention of ß-carotene (Ruel, 2001). According to Lakshmi and Vimala (2000), increased rate of dehydration, as in the case of solar drying versus open-air sun drying, increased the concentration of nutrients and minimized loss of other nutrients such as ascorbic acid. Beta-carotene content in leafy powders, from some vegetables was recorded as $125 \mu g/g$ and $79 \mu g/g$ in solar dried and sun-dried, respectively. The loss of beta-carotene after drying was found to range between 24 and 40% for sun-dried vegetables, and 6 to 25 % for solar dried vegetables. Other researchers, as reported by Lakshmi and Vimala (2000), have presented different reports on the percentage loss of beta-carotene in leafy vegetables after sun and solar drying, but all reports showed higher loss of beta-carotene after sun drying compared with solar drying.

Higher concentrations of beta-carotene content have been found in dried carrots than in fresh produce. This is caused by the removal of water during dehydration. According to the USDA Table of Nutrient Retention Factors (1998), raw carrots provide a maximum of 8052µg/100g edible portion and dehydrated carrots provide 79200µg/100g. Raw sweet potatoes provide 1600µg/100g and raw collard greens provide a maximum of 5400µg/100g. Unfortunately beta-carotene content of dehydrated sweet potatoes and collard greens is not listed.

Vegetable Dimensions and Solar Drier Tray Load

Surface area of the vegetables and the density of loading or packing depth in the solar drier trays have a marked effect on the drying rate. This in turn affects the quality attributes of dried and rehydrated pieces, and acceptability of the final products. By increasing the load of wet materials and the thickness of the wet pieces, drying rate is reduced. Larger vegetable pieces and packing loads would be more economical (less time/labor for cutting and higher yield of dried products per batch), but they would also require longer dehydration time and may not attain low enough moisture content appropriate for long term storage.

For carrots and sweet potatoes the recommended thickness is ¼ in (0.64cm) or 3/8 in carrots (0.96cm). Cut vegetables are normally loaded on trays in layers of varying depths. Loading per sq ft (m^2) of the trays can range from less than 1 lb (450g) to as much as 3 or 4lb (1.4kg or 1.8kg). However, a uniform spread and total weight is very important because too heavy loading may result in slow and uneven drying of vegetables (Luh *et al.*, 1975).

Rehydration

Rehydration can be a difficult and an unsatisfactory process because the removal of water that takes place during dehydration changes the physical properties of the vegetable cells, and that affects the rehydration process of the dried vegetables. Drying causes vegetables' skins to toughen, and makes the permeability of water into the dried food difficult because of loss of osmotic pressure (Rahman and Perera, 1999). Rehydration therefore, is not just a reversal of the drying mechanism. Some structures may not be able to regain their original configuration. In the process, some solutes may leach out into the rehydration medium instead of remaining in the cell tissues to regain the original structure (Luh *et al.*, 1975).

The final moisture content in drying contributes to the elasticity of the cell wall and the swelling power of the vegetables. Both are important for good rehydration. Mazza (1983) observed that rehydration rate was lower for vegetables treated with sucrose, salt, bisulphate, etc., than for vegetables that were steam or water blanched only. He stated that blanching combined with other treatments impaired moisture uptake and removal in carrots. Hence carrots exposed to sucrose or salt treatment yielded more moist finished products compared with untreated samples.

Rehydration ability also depends on the pH of the rehydration medium. Rahman and Perera (1999) reported that Neubert *et al.* (1968) studied the effects of pH of the rehydration medium on the rehydration ability of celery and found no effect on the rehydration of celery that had had no pretreatment. However, Horn and Sterling (1982) found that carrots rehydrated to the greatest extent at pH 12. Most vegetables are rehydrated in cold water before they are prepared or cooked. However other methods of rehydration can be used to enable vegetables to regain their original structure or shape. Adding them into boiling liquids or semi-liquid foods, such as soup, can rehydrate vegetables. The use of boiling liquids has been observed to speed up soaking time. Any rehydration liquid that is unabsorbed should be used during cooking of the vegetables. Most vegetables rehydrate within 1 to 2 hours. If they have to be soaked for more than 2 hrs, they need to be kept in a refrigerator.

Lakshmi and Vimala (2000) reported no difference in the rehydration ratios of sun-dried and solar dried samples. All tested vegetables rehydrated better in boiling water. Premavalli *et al.* (2001) found that all the dehydrated leafy vegetables in their study reconstituted in boiling water within 3 minutes and gave a soft textured product. they calculated the following formula to determine rehydration ratio.

$$\text{Rehydration ratio} = \frac{\text{wt of soaked product}}{\text{Wt of dehydrated product}}$$

The higher the rehydration ratio, the better the dehydrated vegetables rehydrate.

Sensory Evaluation

Sensory evaluation is a scientific discipline used to evoke, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of smell, touch, taste, hearing and sight (Stone and Sidel, 1992). Sensory evaluation is considered a cost-effective resource that plays a major role in the development of a successful product. Affective testing is a method of sensory evaluation that is used to measure consumer acceptance/preference of a product. During affective testing panelists who are untrained are normally involved in an observation and taste testing where they evaluate the product based on their degree of liking/disliking or their preference. Preference refers to the selection of one item over another. Even though panelists for acceptance testing should be persons who have not been trained for discrimination or descriptive testing, they could be recruited based on how frequently they eat the particular type of product. Sometimes recruitment is based on demographic information to find out how the demographic variables may influence product acceptance/preference. The 9-point Hedonic scale is considered to be a very reliable instrument for measuring the degree of liking by untrained panelists (Stone and Sidel, 1992).

Dried vegetables need to be rehydrated and evaluated for overall acceptability of color, flavor and appearance. Lakshmi and Vimala (2000) also evaluated the acceptability of four dried vegetables previously dehydrated by solar drying and open-air sun drying. The mean scores ranged from average to excellent and the color retention was good because of the blanching that was done before drying. However, the flavor of the vegetables was retained to a lesser extent. They suggested that dried vegetables could be used to enrich other food preparations such as stews, if they were acceptable to consumers. Maharaj and Sankat (2000) studied water absorption characteristics of dehydrated dasheen leaves at different hydration temperatures and also investigated the organoleptic characteristics of the dehydrated leaves. They reported that the taste, texture and overall acceptability of water and alkali blanched dasheen leaves that were rehydrated and cooked, were comparable with the freshly harvested cooked leaves. Color was considered best when dasheen leaves were water blanched, dehydrated then reconstituted.

The color and texture and overall acceptability of the cabinet dried vegetables were preferred to the sun- dried vegetables. For appropriate preservation method, steam blanching, followed by chemical treatment and drying in a cabinet drier was recommended. Badifu *et al.* (1995) investigated the effects of blanching, dehydration and storage conditions on beta-carotene of fluted pumpkin leaves and evaluated the quality attributes of the dried leaves. They reported that blanching had a color fixing effect that resulted in aesthetic appeal and overall acceptability.

CHAPTER III

THE EFFECTS OF SOLAR DRYING ON PHYSICAL QUALITY AND BETA-CAROTENE CONTENT OF GREEN LEAFY AND YELLOW SUCCULENT VEGETABLES

Phumzile Mdziniso, Margaret J. Hinds, Gail Gates,
Danielle Bellmer and Barbara Brown

Department of Nutritional Sciences
Oklahoma State University
Stillwater, Oklahoma 74078

ABSTRACT

The effects of vegetable type, vegetable dimensions and load in the solar drier, on rate of dehydration, texture, color, water activity and beta-carotene content were studied among carrots, sweet potato, and collard greens. The results showed that vegetable type significantly affected texture, color, rate of dehydration, and beta-carotene ($p < 0.0001$) but water activity was not affected. Vegetable dimensions significantly affected water activity ($p = 0.0262$). Solar drier load significantly affected water activity ($p = 0.005$) rate of dehydration ($p = 0.0503$) and hue angle ($p = 0 .0427$). Interaction effects were observed between vegetable type and load, and it significantly affected water activity ($p = 0. 01$). The thinner and large thickness and 460g/m^2 load resulted in good color, texture and carotenes in sweet potatoes, whilst the 5mm thick carrots packed at a load of 715g/m^2 were the most economical treatments that yielded the highest beta-carotene and showed good quality properties. After conditioning, the larger (5mm) thick slices of sweet potatoes showed equilibrium moisture content that was slightly higher than the recommended level of $\leq$10%. For collard greens the 2 dimensions and 360g/m^2 loads resulted in the highest β-carotene, good color, texture and water activity. Beta-carotene loss due to solar dehydration was different among the vegetables depending on the initial moisture content. Percent loss ranged from 8.4 to 14.9%, 0.2 to 2.4%, and 18.5 to 28.1% in carrots, sweet potato and collard greens, respectively.

INTRODUCTION

Fresh vegetables constitute a potential source of vitamin A in many developing countries, including Swaziland. They form an essential component of typical Swazi meals by providing variety, carotene and fiber, or as an accompaniment to the traditional staple food, maize porridge. However, in Swaziland as in many countries, availability of fresh vegetables is seasonal.

The solar drying technique has received much emphasis in the tropics to assure vegetable availability during times of scarcity (Onayemi and Badifu, 1987). Solar drying is one of the most popular methods of preservation that has been used in a number of developing countries, such as Tanzania, where the feasibility and implementation of solar driers using locally available products has been tested (Ruel, 2000). It has been found to have great potential for social acceptance because it is the simplest and most economical method of dehydration. Solar drying protects produce from adverse environmental conditions, reduces contamination by microorganisms, increases shelf life of the product, increases micronutrient concentration in the dried products, and shortens drying time (Ruel, 2000). In Swaziland, solar drying is currently being investigated as an alternative method to improve the physical and aesthetic quality of dried materials.

Researchers have reported that open-air sun dried vegetables retained less beta-carotene than oven dried vegetables, (Badifu *et al.*, 1995; Dignos *et al.*, 1992; Yadav and Sehgal, 1995), shade dried (Mosha *et al.*, 1997; Lymo *et al.*, 1991), and solar dried vegetables (Lakshmi and Vimala, 2000; Maeda and Salunkhe, 1981; Negi and Roy, 2000; Gomez, 1981). The rate of β-carotene retention varies with produce type, but the retention range for solar dried vegetables was found to be from 50 to 80% (Ruel, 2001).

According to Esper and Muhlbauer (1998), drying in an appropriate solar drier leads to a reduction of drying time by up to 50% and a significant improvement in product quality in terms of color, texture, flavor and nutrient retention. For vegetables, the dehydration process affects, to a varying degree, the quality attributes of color, texture, and nutrient retention. Such variations in the quality attributes may be due to vegetable type, stage of maturity of the produce, type of pretreatment, load in the solar drier trays, thickness of the vegetable pieces, and the drying method (Onayemi and Badifu, 1987). Quality characteristics are also affected by moisture content and water activity, temperature, relative humidity and rate of dehydration (Luh *et al.,* 1975; Esper and Muhlbauer, 1998).

Several deteriorative reactions that affect the quality attributes of the dehydrated product are initiated during product processing and dehydration and continue into storage. The process of blanching, for example, has been reported (Rahman and Perera, 1999; Onayemi and Badifu, 1987) to improve the color, flavor, texture and nutrient quality (Mosha *et al.,* 1997) of dried vegetables if done under optimum conditions. Yadav and Sehgal (1995) and Badifu *et al.* (1995) reported that blanching had a color fixing effect and resulted in improved aesthetic appeal and overall acceptability of the dried vegetables.

Studies on beta-carotene retention in solar dried vegetables have shown that maximum retention of beta-carotene is obtained by drying vegetables in a solar drier (Maeda and Salunkhe, 1981; Lakshmi and Vimala, 2000; Negi and Roy, 2000; Gomez, 1981), compared with the open air sun drying method because beta-carotene is highly sensitive to direct sunlight (Lymo *et al.*, 1991), heat (Negi and Roy, 2000), air, heat and light (Badifu *et al.*, 1995; Maeda and Salunkhe, 1981; Ruel, 2001; Dignos *et al.,* 1992; Mosha *et al.*,1997).

The purpose of the study was to develop solar drying protocols that would improve physical quality attributes and beta-carotene content of solar dried vegetables that are typically used in Swaziland. The major objectives were to evaluate the effects of vegetable type, thickness, and load of vegetable pieces in the solar drier on rate of dehydration; and color, texture, water activity, and beta-carotene content of solar dried green leafy and yellow succulent vegetables.

MATERIALS AND METHODS

Experimental Design

A 3 x 2 x 2 factorial arrangement was used in a Randomized Complete Block Design to enable 2 process replications. Three vegetable types (sweet potato (*Ipomea batatas*), carrots (*Daucus carota)* and collard greens (*Brassica oleracea*), 2 cut sizes (thickness), and 2 packing loads, in the solar drier were evaluated (Table 1). The particular vegetables were selected because they are considered good sources of vitamin A and are available and eaten by most families in Swaziland.

Table 1

Treatments Applied to Carrots, Sweet Potato and Collard Greens During Dehydration

Vegetable Type	Treatment Codes	Vegetable Dimensions	Vegetable Load in Solar Drier
Carrots	S D	3mm	715g/m^2
	S SH	3mm	430g/m^2
	L D	5mm	715g/m^2
	L SH	5mm	430g/m^2
Sweet Potato	S D	3mm	715g/m^2
	S SH	3mm	430g/m^2
	L D	5mm	715g/m^2
	L SH	5mm	430g/m^2
Collard Greens	S D	2cm	465g/m^2
	S SH	2cm	360g/m^2
	L D	3cm	465g/m^2
	L SH	3cm	360g/m^2

S SH = (small) 3mm thickness and 430g/m^{2}load, L SH = (large) 5mm thickness and 430g/m^{2}load, L D = (large) 5mm thickness and 715g/m^{2}load, S D = (small) 3mm thickness and 715g/m^{2}load (For carrots and sweet potatoes).

S SH = (small) 2cm thickness and 360g /m^{2}load, L SH = (large) 5 mm thickness and 360g /m^{2}load, L D = (large) 5 mm thickness and 465g /m^{2}load, S D = (small) 3 mm thickness and 465g /m^{2}load (For collard greens).

Source and Sample Preparation

Vegetables were randomly assigned to treatments (Appendix 10) and were purchased from local supermarkets in Stillwater. Collard greens were destalked, as is the normal practice in Swaziland, washed in plenty of clean water and allowed to drain. They were cut into 2cm and 3cm wide strips using a sharp kitchen knife. A 30cm/mm plastic ruler (C. Thru^R Ruler Company, CT, USA) was used to measure the width of the leafy vegetables. After thorough washing in clean water, succulent vegetables were peeled and sliced into 3mm and 5mm sizes using a Rival® Food Slicer (Model 1101, Rival Company, Kansas City, MO). The thickness of the succulent vegetables was measured using a 6-inch/150mm Electronic Digital Caliper (Marathon Management Company Ltd; Richmond Hill, Ontario, Canada).

Determination of Blanching Time and Treatment

Prior to the drying process, the shortest blanching time for each of the three vegetables was established using the Peroxidase Test method outlined by Luh and Woodroof (1975). A negative Peroxidase Test determined the blanching time (Appendix 1). To blanch vegetables, a known weight of each prepared vegetable was placed on a perforated stainless steel basket and blanched in a steam-blancher for the specific and shortest time that inactivated the enzymes for each vegetable (Appendix 2). After blanching, vegetables were held in cold storage for 10 minutes to remove excess steam. The succulent vegetables were air dried for 60 minutes using a fan (Lasko Innovators in Home Comfort, Model 2526) to reduce excess water before loading into the solar drier. The collard greens were rotated in a 25-liter salad drier (Dito) for 3 minutes prior to being fanned for 60 minutes.

Drying Vegetables

A solar drier designed and constructed by the Biosystems Engineering Department, Oklahoma State University (OSU), was used for drying all vegetables. The solar drier was designed to hold eight trays with dimensions 22 ″ long x 10″ wide x 1.5″ deep (56cm long x 25cm wide x 4cm deep). This solar drier was of a simple design and construction, consisting of a black box with vents at the base and top of the drier. The lid consisted of a wooden frame covered with a double layer of clear polyethene sheet (Appendix 3).

The blanched and air-dried vegetables were packed into the solar drier trays according to the experimental design. To determine rate of dehydration, temperature and humidity of air within and outside the solar drier, and moisture content were monitored every 2 hours. Sun exposure time was recorded and solar drying was stopped when moisture content of solar dried vegetables reached 8-10%. Samples were equilibrated at room temperature, packed into zipper storage bags, and stored for 4–10 days (22-25°C) in order to remove any residual moisture (conditioning). Moisture content on the dried vegetables was tested again to ensure shelf stability of the dried vegetables (VanGarde and Woodburn, 1994). Rate of dehydration was calculated by dividing the difference between moisture content after air-drying or before dehydration started and final moisture content by total sun exposure hours.

Moisture Determination

Moisture content of the vegetables was determined after post-blanch cooling, air-drying, at 2 hr intervals during dehydration, and after conditioning. Aliquots of 5-10g of leafy vegetables and 3-5g of succulent vegetables were randomly taken from trays and tested for moisture using an IR-30 Moisture Analyzer (Denver Instrument Company, Arvada, CO) according to the manufacturer's recommendations. The instrument was set at 150 ° C and in the percent moisture calculation mode.

Color

Twenty-five (25)g of solar dried collard greens were ground using a commercial blendor (Waring Commercial Blendor 7011, Model 31B192) into powder and loaded into five- 10 ml black plastic containers. Using a Minolta Chroma Meter Reflectance System (CR-200 Ver 3.0 Minolta, Japan), three shots of the contents of each plastic container were taken and its mean used as one data point. Contents of each container were mixed and packed again into the same plastic container three times, so that a total of fifteen (15) data points were obtained for each and every treatment. For dried carrots, 50g carrots were divided into 5 aliquots and loaded into the black plastic containers. These were tapped 15 times to give an even and tight pack and 3 data points taken from each to make 15 data points per treatment. Color for sweet potatoes was measured from 15 slices/pieces of each treatment that were randomly selected. Three shots from each piece were taken and the mean used as one data point. For fresh vegetables the same procedure used for the dried samples was followed. The Colorimeter was set in the CIE L*C*h* mode with illuminator C at 2° observer angle. The CIE system of color measurement is interpreted as follows: L-value represents the degree of lightness or darkness of the food materials (0 = black, 100 = white). The hue angle, h°, is the color descriptor (0 = red, 90 = yellow, 180 = green, 270 = blue). The chroma, C, measures the intensity of the hue. Calibration was based on a white tile with color space chromaticity coordinates of L* = 97.75, h° = 104.0 and C = 2.38.

Texture Analysis

The texture of fresh and dried vegetables was evaluated using 30g of dried carrots and sweet potatoes and 10g dried collard greens. The weighed vegetables were deposited into the sample cup for the TA 65 Multi Puncture Probe (Texture Technologies Corp, Scarsdale, New York) and tapped 15 times to give a tight and even pack. Fresh sweet potato slices were cut into four quarters to facilitate packing into the sample cup. Triplicate tests were carried out using a TA. *XT2i*, Texture Analyzer (Texture Technologies Corp Scarsdale, New York), fitted with a TA 65 Multi Puncture Probe, and a 25-kg load cell. For fresh and dried carrots, sweet potato and collard greens, measurements were taken using the Texture Expert Exceed Software, with the following settings: pre-test speed = 3mm/s, test speed = 1.00mm /s, post test speed 5.0mm/s, distance = 10mm, contact force = 100g, and time = 5 sec. Hardness was interpreted as the maximum force (g) registered when the 14 prongs of the probe traveled a distance of 10mm into the sample.

Water Activity

Water activity was measured from fresh and dried vegetables. For dried vegetables water activity was measured after vegetables were conditioned. This was done to ensure the right moisture content for vegetables for long storage capacity. Rotronic sample cups were used to pack the fresh and dried vegetables to the required level of the cup, and a Rotronic Instrument Water Activity system (Rotronic Instrument Corp, Model A2101, Huntington, NY) was used to take the measurements. Tests were replicated three times.

Beta-Carotene Analysis

Fresh (200g / vegetable) and dried (50g / vegetable) samples of all three types of vegetables were sent by courier to Ralston Laboratory Services, St Louis, for alpha, beta-carotene and Vitamin A activity analysis. Fresh vegetables (200g / vegetable) were packed into Fisher brand sample bags and transported in a cooler with 'Blue Ice' freeze packs to keep them as fresh as possible. Triplicate samples from each treatment were prepared, and a total of 72 dried and 9 fresh samples were sent for analysis.

Data Analysis

The Statistical Analysis System (SAS), Release 8.1 for Microsoft® Windows, was used for processing the data. Proc Mixed and Least Squares Means were used to determine the effect of vegetable type and dimensions and solar drier load on physical properties and carotenoids between the different treatments. Temperature and humidity inside and outside the solar drier were considered confounding variables and were measured with the dependent variables. The assumption was that there was going to be a correlation between humidity, temperature in and outside the solar drier and the rate of dehydration and other dependent variables. To avoid the influence of the covariates on the results of the study, humidity and temperature were analyzed as covariance parameters. Duncan's Multiple Range Test was also used to compare differences between treatments.

RESULTS AND DISCUSSION

Effects of Vegetable Type on the Properties of Fresh Vegetables

Fresh carrots and sweet potato had similar hue of orange-yellow (h° = 60.0 ± 1.32 to 60.9 ± 1.38) and collard greens were a pale green (h° = 124.3 ± 1.34). Carrot color was more intense (chroma = 58.8 ± 2.93) than sweet potatoes (chroma = 52.4 ± 1.70) which were a whitish orange-yellow as seen by their L-value of 72.1 ± 0.79. The pale green color of collard greens was not very intense (chroma-20.0 ± 3.58) and had a dark background indicated by the low L-value (29.3 ± 6.73). The initial moisture content of carrots was 88% and carrots were harder (6111.6 ± 497.55g force) than sweet potato (2308.5 ± 1346.07g force) whose initial moisture was 76 %. Collard greens had the highest moisture of 94% when they were fresh and their texture was the most soft (66.49 ± 11.38g). Alpha, and total carotene were highest in fresh carrots whilst fresh sweet potato and collard greens showed similar amounts (Table 2). Water activity, alpha, beta and total carotene were similar between sweet potato and collard greens but color, texture, and rate of dehydration were different. Carrots and sweet potato had similar hue, rate of dehydration, moisture content and beta-carotene but their other properties were different (Table 2).

Table 2

Effects of Vegetable Type on Properties of Fresh Carrots, Sweet Potato and Collard Greens

Property	Carrots	Sweet Potato	Collard Greens
Hue angle°	60.9 ± 1.38^{b}	60.0 ± 1.32^{b}	124.3 ± 1.34^{a}
Chroma	58.8 ± 2.93^{a}	52.4 ± 1.70^{b}	20.0 ± 3.58^{c}
L- value	58.3 ± 2.34^{b}	72.1 ± 0.79^{a}	29.3 ± 6.73^{c}
Texture (g) Shear force	6111.6 ± 497.55^{a}	2308.5 ± 1346.07^{b}	66.49 ± 11.38^{c}
Water activity	0.97 ± 0.01^{b}	0.99 ± 0.003^{a}	0.99 ± 0.003^{a}
Rate of dehydration (% moisture loss /hr)	3.3 ± 0.39^{gh}	3.8 ± 0.20^{efg}	6.3 ± 0.1^{abcd}
Moisture (%)	88	76	94
Alpha carotene (mg/100g)	1.46 ± 0.26^{a}	0.03 ± 0.01^{b}	0.02 ± 0.0005^{b}
Beta carotene (mg/100g)	3.1 ± 0.5^{a}	2.35 ± 0.61^{a}	2.36 ± 0.10^{a}
Total carotene (mg/100g)	6.35 ± 1.03^{a}	3.95 ± 1.02^{b}	3.96 ± 0.17^{b}

Means for a particular property (in the same row) between Tables 2, 5, 6 and 7 followed by the same letter are not significantly different at $\alpha = 0.05$ (Duncan's Multiple Range Test)

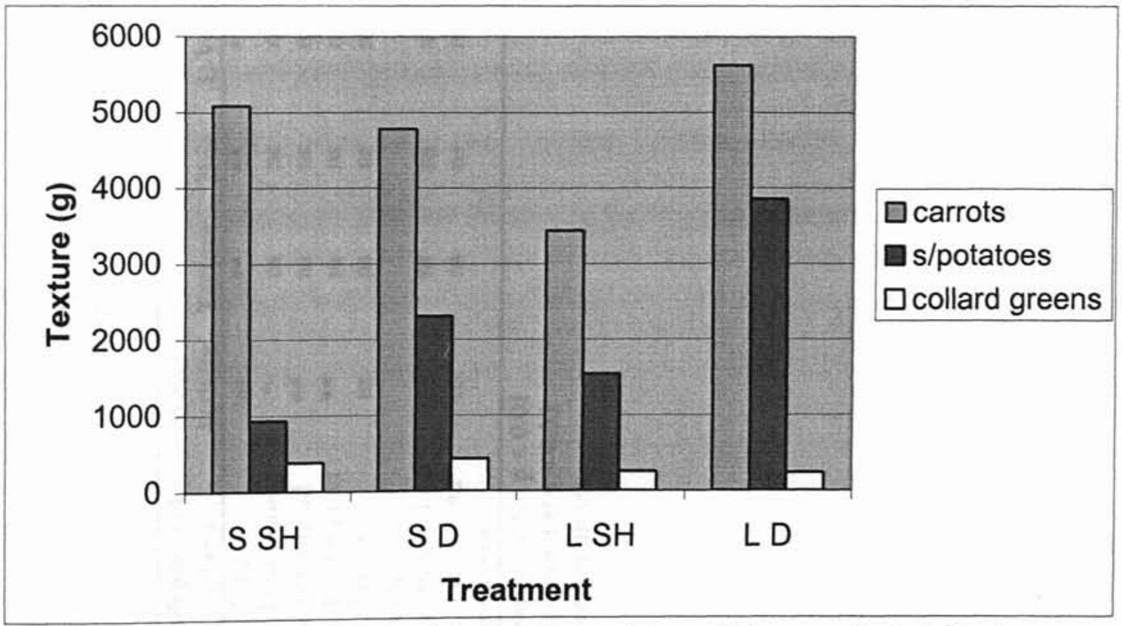
Effects of Vegetable Type on the Properties of Dehydrated Vegetables

Analysis of Variance by the PROC MIXED procedure of SAS indicated that vegetable type significantly affected texture, L-value, hue, chroma, alpha, beta, and total carotenes and rate of dehydration of dehydrated vegetables, but not their water activity (Table 3). Significant differences in texture were observed between carrots and sweet potato ($p = 0.0024$), carrots and collard greens ($p < 0.0001$), and sweet potato and collard greens ($p = 0.0174$). Carrots had more firm texture than sweet potato and collard greens. Sweet potatoes were firmer than collard greens (Figure 1). There were significant differences ($p < 0.01$) in hue, L-value, chroma due to vegetable type. Carrots were orange even when dehydrated which is indicated by their hue angle that ranged from 48.9 ± 1.8 to 50.0 ± 2.4, and sweet potatoes were orange-yellow indicated by their hue angle that ranged from 53.2 ± 2.0 to 56.79 ± 2.6. Chroma was higher for sweet potatoes (41.5

± 3.3 to 45.4 ± 4.8) than for carrots (21.2 ± 23.0 ± 4.2) (Table 6). Collard greens were more of a pale green that was less intense after dehydration with a darker background that was shown by their hue, chroma and L-value (Table 7). Significant differences were also observed in alpha carotene content between carrots and sweet potato ($p < 0.0001$), and carrots and collard greens ($p < 0.0001$), but not between sweet potato and collard greens ($p = 0.9208$). Carrots and sweet potato showed significant differences ($p < 0.01$), and collard greens and sweet potato showed significant differences ($p < 0.01$) in beta and total carotene content. Collard greens had more beta and total carotene than the sweet potato after dehydration. There were no significant differences ($p > 0.05$) in beta and total carotene content between carrots and collard greens (Table 4a).

Figure 1

Effects of Vegetable Type on Texture of Dehydrated Vegetables



S SH = (small) 3mm thickness and 430g/m^{2}load, S D = (small) 3mm thickness and 715g/m^{2}load,
L SH = (large) 5mm thickness and 430g/m^2 load, L D = (large) 5mm thickness and 715g/m^{2}load,

Table 3

Influence of Vegetable Type, Vegetable Dimension and Solar Drier Load on the Dependent Variables (Results of Proc Mixed)

Independent Variable	Water Activity	Texture	Hue	L-Value	Chroma	Alpha Carotene	Beta Carotene	Total Carotene	Rate of Dehydration
Veg. Type	ns	**	**	**	**	**	**	**	**
Veg. Dimension	*	ns	ns	ns	ns	ns	ns	ns	ns
Solar Drier Load	**	ns	ns	ns	ns	ns	ns	ns	*
Veg. Type x Load	**	ns	ns	ns	ns	ns	ns	ns	ns
Veg. Type x Dimensions	ns	ns	ns	ns	ns	ns	ns	ns	ns
Dimensions x load	ns	ns	ns	ns	ns	ns	ns	ns	ns
Veg. Type x load x dimensions	ns	ns	ns	ns	ns	ns	ns	ns	ns

** Significant at $p < 0.01$
* Significant at $p < 0.05$
ns not significant

Table 4a

LSMeans Effects of Vegetable Type on Properties of Dehydrated Vegetables

Property	Carrots vs Sweet Potato	Carrots vs Collard Greens	Sweet Potato vs Collard Greens
Water Activity	p = 0.1192	p = 0.2369	p = 0.6727
Texture (g)	p = 0.0024	p < 0.0001	p = 0.0174
Hue	p =0.0067	p < 0.0001	p < 0.0001
L-value	p = 0.0001	p = 0.0039	p < 0.0001
Chroma	p < 0.0001	p < 0.0001	p < 0.0001
Alpha Carotene	p < 0.0001	p < 0.0001	p = 0.9208
Beta-Carotene	p = 0.0120	p = 0.0553	p = 0.0003
Total Carotene	p = 0.0002	p = 0.8039	p = 0.0004
Rate of Dehydration	p =0.1686	p = 0. 0001	p =0.0001

Effects of Vegetable Dimensions on the Properties of Dehydrated Vegetables

Vegetable dimensions (3mm vs 5mm thick) for carrots and sweet potato, and 2cm vs 3cm width for collard greens significantly affected water activity ($p = 0.0262$) of the dehydrated vegetables (Tables 3 and 4b). Texture, L-value, chroma, rate of dehydration, alpha, beta and total carotene was not influenced by vegetable dimensions (Tables 3 and 4b).

Table 4b

LSMeans Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Vegetables

Property	Vegetable Dimensions	Solar Drier Load
Rate of dehydration (% moisture loss/hr)	p = 0.7596	p = 0.0503
Water activity	p = 0.0262	p = 0.0050
Texture (g)	p = 0.7473	p = 0.1100
Hue	p = 0.3341	p = 0.0427
L-value	p = 0.5494	p = 0.3668
Chroma	p = 0.7120	p = 0.3765
Alpha carotene	p = 0.9051	p = 0.3205
Beta-carotene	p = 0.5615	p = 0.2998
Total carotene	p = 0.5529	p = 0.3967

Effects of Solar Drier Load on the Properties of Dehydrated Vegetables

Significant differences were observed in water activity (p = 0.0050), rate of dehydration (p = 0.0503) and hue (p = 0.0427) due to solar drier load (Tables 3 and 4b). No significant differences (p > 0.05) in texture, chroma, l-value, alpha, and beta-carotene content were observed due to solar drier load (Tables 3 and 4b).

Interaction Effects of Independent Variables

Interaction effects between vegetable type and load did not affect properties of dehydrated vegetables except water activity (Table 3).

Effects of Vegetable Dimensions and Solar Drier Load on Treatments of Individual Vegetables

Tables 5, 6, and 7 give a summary of the results that show the effects of thickness and load on the properties of dehydrated carrots, sweet potato and collard greens for each treatment. The vegetable treatments were previously explained in the Experimental Design (Table 1).

Water Activity

Water activity, represents the quantity of unbound water available in the vegetables that can cause deteriorative reactions. Optimum water activity for food differs among specific foods. Therefore, water activity of a food determines whether it would be susceptible to spoilage by microorganisms or whether it would have a long shelf life. For dried vegetables, water activity of 0.6 is recommended in order to prevent spoilage from microbial proliferation (VanGarde and Woodburn, 1994; McWilliams, 2001). Solar drier load of collard greens affected water activity of the dehydrated vegetables. Higher than recommended water activity levels that is, >0.6 were observed among the deeper loads of collard greens (S D & L D, Table 7). The shallow load in collard greens had lower values of water activity (Table 7 and Figure 2). However in the case of carrots, water activity was lower in shallow loads and the thinner slices only (Table 5 and Figure 2), whereas it was higher on shallow loads for thick sweet potato slices (Table 6 and Figure 2).

Table 5

Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Carrots

Property	Dehydrated Carrot Treatment			
	S SH	**S D**	**L SH**	**L D**
Hue angle °	49.6 ± 1.73 ^{g}	50.0 ± 2.38 ^{g}	49.7 ± 2.95 ^{g}	48.9 ± 1.84 ^{g}
Chroma	22.3 ± 3.47 ^{d}	21.8 ± 4.12 ^{d}	21.2 ± 3.84 ^{d}	23.0 ± 4.17 ^{d}
L- value	29.4 ± 4.39 ^{d}	28.2 ± 4.89 ^{de}	32.3 ± 4.88 ^{c}	28.6 ± 4.74 ^{de}
Texture (g) shear force	5081.5 ± 4962.34 ^{ab}	4773.0 ± 3256.63 ^{ab}	3441.6 ± 1690.80 ^{abcd}	5626.0 ± 4104.12 ^{a}
Water activity	0.56 ± 0.011 ^{f}	0.59 ± .022 ^{de}	0.63 ± 0.003 ^{ab}	0.615 ± 0.017 ^{bc}
Rate of dehydration (Moisture Loss % /hr)	3.2 ± 0.25 ^{g}	3.3 ± 0.47 ^{g}	3.3 ± 0.39 ^{g}	3.0 ± 0.24 ^{h}
Alpha carotene (mg/100g)	7.9 ± 2.39 ^{ab}	7.3 ± 4.03 ^{ab}	5.9± 1.45 ^{b}	9.7 ± 3.87 ^{a}
Beta carotene (mg/100g)	12.9 ± 2.72 ^{bcd}	11.9 ± 4.87 ^{bce}	9.8 ± 1.9 0^{def}	15.5 ± 3.80 ^{bc}
Total carotene (mg/100g)	28.2 ± 6.39 ^{ab}	25.9 ± 11.39 ^{abc}	21.2 ± 4.32 ^{bcd}	33.9 ± 9.50 ^{a}

Means for a particular property (in the same row) between Tables 2, 5 – 7 followed by the same letter are not significantly different at $\alpha = 0.05$ (Duncan's Multiple Range Test). L SH = (large) 5mm thickness and 430g/m^2 load, L D =(large) 5mm thickness and 715g/m^2 load, S SH = (small) 3mm thickness and 430g/m^2 load
S D = (small) 3mm thickness and 715g/m^2 load.

Table 6

Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Sweet Potato

Property	Dehydrated Sweet Potato Treatment			
	S SH	S D	L SH	L D
Hue angle °	56.0 ± 2.08 ^{e}	56.0 ± 2.16 ^{e}	56.79 ± 2.56 ^{e}	53.2 ± 1.98 ^{f}
Chroma	43.9 ± 3.53 ^{ab}	43.2 ± 3.6 0^{bc}	45.4 ±4.76 ^{a}	41.5 ± 3.33 ^{c}
L- value	50.48 ± 3.53 ^{a}	51.2 ± 2.99 ^{a}	52.58 ± 4.60 ^{a}	47.6 ± 2.65 ^{b}
Texture (g) shear force	927.93 ± 601.79 ^{de}	2307.6 ± 1204.31 ^{bcde}	1542.58 ±610.39 ^{cde}	3853.5 ±1608.55 ^{abc}
Water activity	0.58 ± 0.002 ^{def}	0.56 ± 0.025^{f}	0.61 ± 0.009 ^{dc}	0.575 ± 0.004 ^{ef}
Rate of dehydration (moisture loss % /hr)	3.8 ± 0.20 ^{f}	3.3 ± 0.60 ^{g}	4.1 ± 0.56 ^{e}	3.3 ± 0.16 ^{g}
Alpha carotene (mg/100g)	0.1 ± .02 ^{c}	0.09 ± .0.028 ^{c}	0.11 ± .016 ^{c}	0.07 ±. 026 ^{c}
Beta carotene (mg/100g)	8.32 ± 1.92 ^{def}	6.5 ± 1.88^{f}	9.2 ± 1.48 ^{def}	7.35 ± 1.1 ^{ef}
Total carotene mg/100g)	13.99 ± 3.23 ^{de}	11.0 ±3.16 ^{e}	15.5 ± 2.51 ^{ed}	12.35 ± 1.8 ^{e}

Means for a particular property (in the same row) between Tables 2 and 5 – 7, followed by the same letter are not significantly different at $\alpha = 0.05$ (Duncan's Multiple Range Test). L SH = (large) 5mm thickness and 430g/m^2 load, L D = (large) 5mm thickness and 715g/m^2 load, S SH = (small) 3mm thickness and 430g/m^2 load, S D = (small) 3mm thickness and 715g/m^2 load.

Table 7

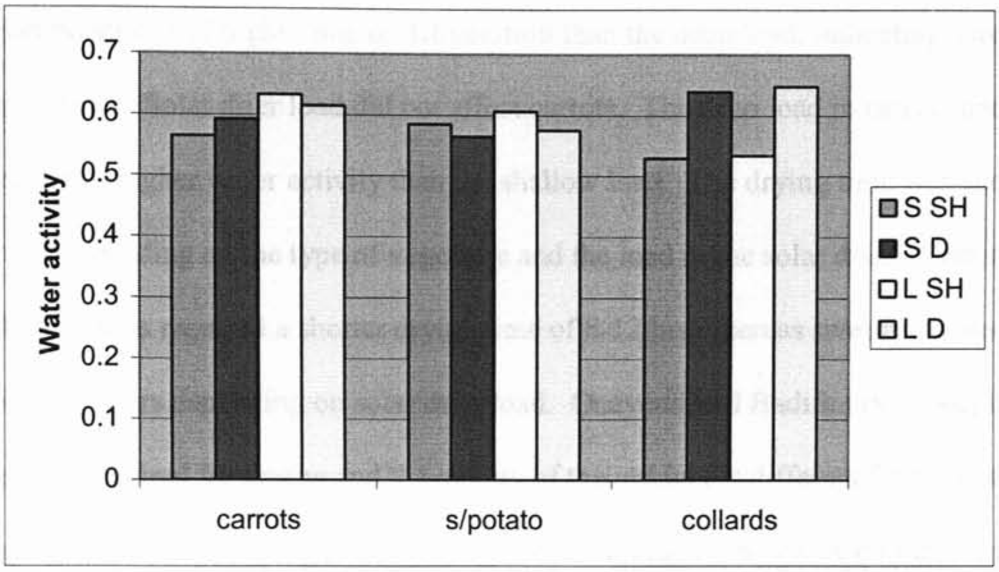
Effects of Vegetable Dimensions and Solar Drier Load on Properties of Dehydrated Collard Greens

Property	**Dehydrated Collard Greens Treatment**			
	S SH	**S D**	**L SH**	**L D**
Hue angle °	114.2 ± 4.53 ^{a}	105.4 ± 4.20 ^{c}	110.7 ± 7.08 ^{b}	103.2 ± 5.77 ^{d}
Chroma	10.9 ± 2.31^{e}	9.7 ± 1.84 ^{e}	9.1 ± 2.08 ^{e}	9. 5 ± 2.15 ^{e}
L- value	25.6 ± 4.69 ^{g}	26.6 ± 6.07 ^{ef}	22.3 ± 3.5 ^{h}	23.8 ± 3.80 ^{gh}
Texture (g) Shear force	385.3 ± 141.60 ^{d}	422.4 ± 246.14 ^{cd}	258.2 ± 156.92 ^{d}	236.8 ± 70.59 ^{d}
Water activity	0.53 ± 0.001 ^{g}	0.64 ± 0.009 ^{a}	0.53 ± 0.044^{g}	0.64 ±0.01^{a}
Rate dehydration (moisture loss %/hr)	6.3 ± 0.10 ^{a}	5.5 ± 0.14 ^{d}	6.2 ± 0.64 ^{b}	5.7 ± 0.84 ^{d}
Alpha carotene mg/100g)	0.2 ± 0. 05 ^{c}	0.1 ± .04 ^{c}	0.2 ± .05 ^{c}	0.2 ± 0.04 ^{c}
Beta carotene mg/100g)	19.9 ± 5.58 ^{a}	10.5 ±1.38 ^{def}	16.4 ± 4.48 ^{ab}	16.5 ± 6.25 ^{ab}
Total carotene mg/100g)	33.5 ± 9.32 ^{a}	17.7 ± 2.35 ^{bcd}	27.6 ±7.45 ^{ab}	27.7 ± 10.50 ^{ab}

Means for a particular property (in the same row) between Tables 2, and 5-7, followed by the same letter are not significantly different at $\alpha = 0.05$ (Duncan's Multiple Range Test). L SH = (large) 3 cm thickness and 360g/m^2 load, L D = (large) 3cm thickness and 465/m^2 load, S SH = (small) 2cm thickness and 360g/m^2 load
S D = (small) 2cm thickness and 465g/m^2 load.

Figure 2

Effects of Solar Drier Load on Water Activity

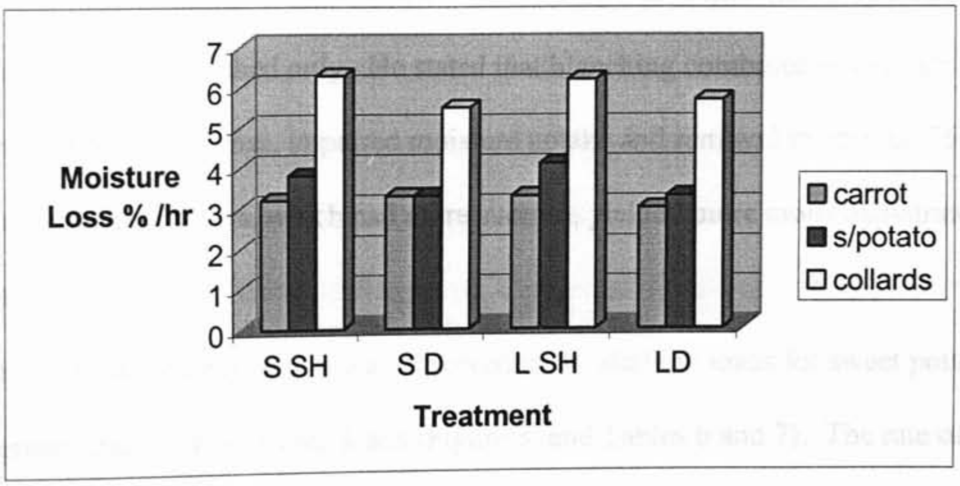


S SH = (small) 3mm thickness and 430g/m^{2}load, S D = (small) 3mm thickness and 715g/m^{2}load, L SH = (large) 5mm thickness and 430g /m^2 load, L D = (large) 5mm thickness and 715g/m^{2}load.

Rate of Dehydration

Figure 3

Effects of Vegetable Type and Solar Drier Load on Rate of Dehydration



S SH = (small) 3mm thickness and 430g/m^{2}load, S D = (small) 3mm thickness and 715g/m^{2}load, L SH = (large) 5mm thickness and 430g/m^2 load, L D = (large) 5mm thickness and 715g/m^{2}load.

Figure 3, and Appendix 4.1- 4.3 show the dehydration pattern of carrots, sweet potato, and collard greens in their solar drier load. The shallow load in collard greens and sweet potatoes had higher rate of dehydration than the deep load, indicating shorter drying time. Solar drier load did not affect carrots. The deep load in carrots and collard greens had higher water activity than the shallow load. The drying time was shorter or longer depending on the type of vegetable and the load in the solar drier. Carrots and collard greens required a shorter drying time of 8-12 hrs whereas sweet potatoes required from 10-14 hrs depending on solar drier load. Onayemi and Badifu (1987) explained that the time required for drying and the quality of the product is different from vegetable to vegetable, and could be affected by many factors including moisture content of produce, its water activity, temperature during drying, relative humidity, any pretreatment given to the food, velocity of air in the drier and the type of the food.

Dehydration rate was lower in the deeper solar drier loads. The rate of dehydration was lowest in treatment L D in dehydrated carrots and in treatments L D and S D for sweet potato (Tables 5 and 6). Mazza (1983) observed that vegetables, when treated with sucrose during blanching, had a lower dehydration rate than vegetables that were steam or water blanched only. He stated that blanching combined with other treatments, including sucrose, impaired moisture uptake and removal in carrots. Hence, in this study sweet potatoes, which had more sucrose, yielded more moist dehydrated products.

Higher rate of dehydration was observed in the shallow loads for sweet potato and collard greens than in their deeper loads (Figure 3, and Tables 6 and 7). The rate of moisture removal was expected to be slower in deeper loads than shallow loads.

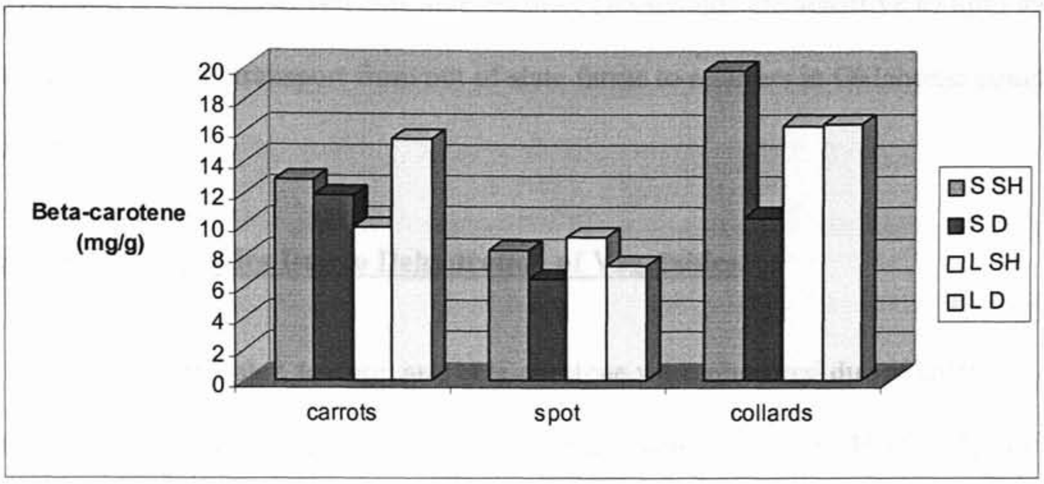
Reducing the packing load of vegetables in the solar drier could increase rate of dehydration and shorten drying time. However, the recommended vegetable size depends on the end use of the product because it should represent the consumer's requirement for that particular size and need for rapid drying.

Beta-Carotene

Beta-carotene concentration after dehydration remained higher in carrots and collard greens and lower in sweet potatoes (Table 9). The higher concentration was caused by the removal of water in the food during dehydration. Collard greens showed the highest beta–carotene concentration (10.5 ± 1.38 to19.9 ± 5.58) than carrots (9.8 ± 1.90 to15.5 ± 3.80) or sweet potato (6.5 ± 1.88 to9.2 ± 1.48). These results were not expected because orange colored vegetables were expected to have more beta-carotene than green leafy ones. The fact that carrots and sweet potatoes contain more sugar than collard greens, could have contributed to the decrease in beta-carotene content. The sugar increases water retention thus prolonging drying time and more breakdown of beta-carotene such that by the time the vegetable was dried, more beta-carotene was lost, as beta-carotene is highly sensitive to direct sunlight (Lymo *et al.*, 1991), heat (Negi and Roy, 2000), air, heat and light (Badifu *et al.*, 1995; Maeda and Salunkhe, 1981; Ruel 2001; Dignos *et al.*, 1992; Mosha *et al.*, 1997). A positive relation was found between beta-carotene content and rate of dehydration. Carrot and sweet potato treatments had longer drying times than collard greens (Figure 4 and Appendix 4). Hence collard greens had more beta-carotene after drying for a shorter time than carrots and sweet potatoes that had longer drying time and less beta-carotene.

Figure 4

Effects of Vegetable Type on Beta-Carotene of Dehydrated Carrots, Sweet Potatoes, and Collard Greens



S SH = (small) 3mm thickness and 430g/m^2load, S D = (small) 3mm thickness and 715g/m^2load, L SH = (large) 5mm thickness and 430g/m^2 load, L D = (large) 5mm thickness and 715g/m^2load.

The beta-carotene content of collard greens compared well with beta-carotene concentration found in some solar dried leafy vegetables like amaranth (11.8 ± 0.8) and fenugreek (15.9 ± 0.7), but was lower than the amount found in Savoy beet (28.6 ± 2.6) (Negi and Roy, 2000). Mosha *et al.* (1997) also found 19.12mg/100g of beta-carotene in amaranth and less in pumpkin, sweet potato leaves, peanut and cowpea leaves.

Total Carotenoids

Carrots and collard greens contained more total carotenoids than sweet potatoes (Tables 5, 6, and 7). The results did not agree well with reports of Mosha *et al.* (1997) because the amount of carotene retained after drying differs from vegetable to vegetables. They reported total carotene to range from 26.79mg/100g to 44.74mg/100g. In this study collard greens had the highest total carotenes among the selected vegetables but they still ranged from 14mg/100g to 33.47mg/100g, which was below the levels Mosha *et al.*

(1997) reported. The differences could have been caused by many factors that affect quality of dried product, such as temperature during drying, relative humidity, rate of dehydration and length of sun exposure because carotenoids are sensitive to light and heat. Losses during transport from out of state farms to retailers in Oklahoma could have occurred.

Changes in Properties Due to Dehydration of Vegetables

Changes in color, texture, and beta-carotene were observed due to solar dehydration. The hue angle that was orange-yellow was reduced by 10.9° to 12° in dehydrated carrots, and by 3.21° to 7.8° in dehydrated sweet potatoes (Table 8). Though carrots and sweet potatoes lost some of the color, they were still orange. The chroma decreased by 7.2° to 10.9° in sweet potatoes, and by 37.6° to 35.8° in dehydrated carrots, indicating that the color of carrots was less intense when dried. Looking at the L-value sweet potatoes showed a whiter background after solar dehydration than carrots (-26 to 30.1 vs sweet potatoes with -19.5 to -24.5). The hue angle of the dehydrated collard greens was reduced by 10.1 to 18.9°. Chroma and L-value were reduced by dehydration from 9.1 to 10, and 9.1 to 10.9 for carrots and sweet potatoes, respectively.

Texture in carrots was reduced by 485g to 2669g in the different treatments after dehydration (Table 8). Dehydration parameters caused texture of L D treatment in sweet potatoes to become firmer, but that of treatments S SH and L SH to become softer (Table 8). All collard greens treatments became firm after dehydration (Table 8).

Table 8

Changes in Color and Texture in Carrots, Sweet Potatoes, and Collard Greens Due to Solar Dehydration

Property	**Solar Dehydration Treatment**			
Carrots	**S SH**	**S D**	**L SH**	**L D**
Hue angle (°)	-11.3	-10.9	-11.2	-12.0
Chroma	-36.5	-37.0	-37.6	-35.8
L- value	-28.9	-30.1	-26	-29.7
Texture (g) shear force	-1030	-1338	-2669	-485
Sweet Potatoes				
Hue angle	-4.0	-4.0	-32.1	-6.8
Chroma	-8.5	-9.2	-7.0	-10.9
L- value	-21.6	-20.9	-19.5	-24.5
Texture (g) shear force	-1380	-0.4	-766	+1545
Collard Greens				
Hue angle	-10.1	-18.9	-13.6	-21.1
Chroma	-9.1	-10.3	-10.9	-10.5
L- value	-3.7	-2.7	-7.0	-5.5
Texture (g) shear force	+318.8	+355.9	+191.51	+170.3

S SH = (small) 3mm thickness and 430g/m^2 load, S D = (small) 3mm thickness and 715g/m^2 load, L SH = (large) 5mm thickness and 430g/m^2 load, L D = (large) 5mm thickness and 715g/m^2 load.
(-) vegetable was less firm after dehydration, (+) vegetable was more firm after dehydration

Table 9 shows percent of beta-carotene lost due to dehydration of carrots, sweet potato and collard greens. Vegetable dimensions and solar drier load had no effect on beta-carotene content of dried vegetables. Beta-carotene lost was different between vegetable types depending on the amount of moisture that was contained in the fresh vegetable. Carrots had the highest moisture of 90.4%, sweet potatoes had 76% and collard greens had 89%. Fresh collard greens contained 21.8% beta-carotene (dry weight basis). The dried collard greens had between 11.9 to 21.5% beta-carotene among treatments. Therefore, percentage loss ranged from 0.3 to 9.9% in the different treatments (Table 9). Fresh carrots had 32.3% beta-carotene and dried carrots had between 10.9 to 17.4% beta-carotene (dry weight basis). Percentage of beta-carotene lost ranged from 14.9 to 19.5% among the treatments. Sweet potatoes had the lowest moisture and beta-carotene when fresh than the other vegetables (10%). The dried sweet potatoes contained between 7.6 to 9.8% beta-carotene (dry weight basis). Hence, loss was between 0.2 to 2.4% among the treatments (Table 9). There have been different reports by different researchers on beta-carotene loss due to drying methods in green leafy vegetables ranging from 6% to 25 % in a cabinet dryer (Lakshmi and Vimala 2000). Some researchers have reported retention percent to be as high as 50 % and more (Ruel, 2000). Yadav and Sehgal (1995) also compared sun and oven drying and reported a loss of 14% in oven drying in leafy vegetables. Other researchers reported considerable loses of beta-carotene but the percent was not reported. Collard greens compared well with some of these reports and for carrots and sweet potatoes no reports on percent loss were found.

Table 9

Percent Loss in Beta-Carotene Content Due to Solar Dehydration of Carrots, Sweet Potato, and Collard Greens

Vegetable Type and Treatment	Initial Moisture (%)	Final Moisture (%)	β-Carotene in Fresh Vegetables (mg/100g)	β-Carotene (%) in Fresh Vegetables (d.b.)	β-Carotene in Dried Vegetables (mg/100g)	β-Carotene (%) in Dried Vegetables (d.b.)	% Loss*
Carrots							
SSH	90.4	9	3.1	32.3	13	14.2	18.1
SD	90.4	7	3.1	32.3	12	12.9	19.4
LSH	90.4	9	3.1	32.3	10	10.9	17.4
LD	90.4	8	3.1	32.3	16	17.4	14.9
Sweet Potato							
SSH	76	10	2.4	10	8	8.9	1.2
SD	76	8	2.4	10	7	7.6	2.4
LSH	76	9	2.4	10	9	9.78	0.2
LD	76	11	2.4	10	7	7.6	2.4
Collard Greens							
SSH	89	7	2.4	21.8	20	21.5	0.3
SD	89	8	2.4	21.8	11	11.9	9.9
LSH	89	7	2.4	21.8	16	17.2	4.6
LD	89	8	2.4	21.8	17	18.5	3.3

* % Loss Beta-Carotene Calculated on Dry Weight Basis

Equilibrium Moisture Content

After conditioning moisture contents were different among vegetable treatments. Final equilibrium moisture contents were 5.0 ± 1.16 to 7.1 ± 1.17%, 7.4 ± 0.70 to 11.3 ± 1.03 %, 5.7 ± 1.33 to 6.2 ± 0.65 for carrots, sweet potatoes, and collard greens, respectively. The larger dimensions of sweet potatoes showed moisture content (10.61 ± 1.41 to 11.3 ± 1.03%) that was above the recommended level of $\leq 10\%$. This higher moisture content might have been caused by the fact that sweet potatoes have more sugar than carrots and collard greens because sugar is very hydroscopic. However, all treatments of dehydrated collard greens and carrots had moisture that was within the recommended $\leq 10\%$ level. Final moisture contents were comparable with those reported by Negi and Roy (2000), who studied the effects of blanching and drying methods on beta-carotene in selected leafy vegetables, and solar dried them until they contained 7-9% moisture. Luh *et al.* (1975) reported that final moisture content of the dehydrated vegetables could influence the quality of the dehydrated vegetables and ß-carotene content.

Conclusion

Vegetable type had a marked effect on the properties of dried products. The results of this study showed rate of dehydration, color, texture, and β-carotene content were significantly different depending on the type of vegetable but water activity was the same. Load in the solar drier significantly affected water activity and rate of dehydration of the dehydrated vegetables but not the other properties. Thickness of the vegetables, significantly affected water activity of the carrots, sweet potato and collard greens.

Dehydrated carrots and collard greens contained more β-carotene than dehydrated sweet potatoes. The large thickness (5mm) and deep (715g/m^2) load in carrots (L D) gave good color, water activity level, final moisture content, and high amount of beta, alpha, and total carotene than the other carrot treatments. The rate of dehydration was less because of the thickness and load. However, that did not affect the carotene content of the dehydrated carrots. This treatment would be the most economical for carrots in terms of the time spent for preparation of the vegetables and quantity of produce that could be dehydrated at one time.

For sweet potatoes the 3mm thick and large thickness and 460g/m^2 load (S SH, S D, L SH) gave good and similar color, texture, fair amounts of alpha, beta and total carotene. Treatment L SH would be more economical but its equilibrium moisture content, which is an important property for shelf-stability, was slightly higher than the recommended 10% level.

Among the collard greens, treatments with highest β-carotene were S SH, L SH and L D but L D was more yellow than S SH and had a higher water activity level. However L D would be the most economical treatment. For collard greens, the treatment that would give the best properties would be the 2cm thickness and 360g/m^2 load (S SH) based on all its color texture, water activity, moisture content, carotenoids and rate of dehydration but it is the least economical treatment. The 3cm thickness and 360g/m^2 and 465g/m^2 loads (L SH and L D) also resulted in high beta-carotene content and had good rate of dehydration, moisture content, texture and color that were fairly similar but water activity was above the recommended level required for longer storage. Hence, treatment L SH would be a better treatment because the time spent preparing the vegetables would

Dehydrated carrots and collard greens contained more *β*-carotene than dehydrated sweet potatoes. The large thickness (5mm) and deep (715g/m^2) load in carrots (L D) gave good color, water activity level, final moisture content, and high amount of beta, alpha, and total carotene than the other carrot treatments. The rate of dehydration was less because of the thickness and load. However, that did not affect the carotene content of the dehydrated carrots. This treatment would be the most economical for carrots in terms of the time spent for preparation of the vegetables and quantity of produce that could be dehydrated at one time.

For sweet potatoes the 3mm thick and large thickness and 460g/m^2 load (S SH, S D, L SH) gave good and similar color, texture, fair amounts of alpha, beta and total carotene. Treatment L SH would be more economical but its equilibrium moisture content, which is an important property for shelf-stability, was slightly higher than the recommended 10% level.

Among the collard greens, treatments with highest *β*-carotene were S SH, L SH and L D but L D was more yellow than S SH and had a higher water activity level. However L D would be the most economical treatment. For collard greens, the treatment that would give the best properties would be the 2cm thickness and 360g/m^2 load (S SH) based on all its color texture, water activity, moisture content, carotenoids and rate of dehydration but it is the least economical treatment. The 3cm thickness and 360g/m^2 and 465g/m^2 loads (L SH and L D) also resulted in high beta-carotene content and had good rate of dehydration, moisture content, texture and color that were fairly similar but water activity was above the recommended level required for longer storage. Hence, treatment L SH would be a better treatment because the time spent preparing the vegetables would be less even if it meant less quantity of vegetables per drying batch and yet yield high beta-carotene.

Recommendations

1. Swazi people should be educated on the use of solar driers as an appropriate preservation technique that can be socially accepted in terms of its simplicity to make and use. Solar driers could be constructed using locally available raw materials. Appropriate vegetable dimensions and solar drier packing load to retain maximum levels of β-carotene must be ascertained, and the information disseminated.
2. An integrated approach should be used with the promotion of solar driers such that it is combined with other programs like nutrition education (for them to understand the role or importance of nutrients, how these nutrients can be retained or lost), safety and handling, appropriate food preparation practices. The approach should involve agricultural extension support that would promote cultivation of appropriate cultivars, home economics extension workers and public health personnel who would ensure primary health care (deworming, sanitation).
3. People should be encouraged to use the most economical method that would still give the best results.
4. Since succulent vegetables can be dried successfully, the surplus sweet potato and carrots should be dried to enable their use even when they are out of season.

5. Dehydration of sweet potatoes should be encouraged to prevent post-harvest spoilage and improve food security. Whatever amount of beta-carotene that would be retained, could improve the beta-carotene content of other dishes.

Future Research

Since succulent vegetables are not commonly dehydrated in Swaziland, the same study could be done for other types of succulent vegetables and fruits that are locally produced (pumpkins, mangoes, paw-paw and guavas) including the indigenous fruits and vegetables.

One could look into development of new products that would improve and encourage incorporation of β-carotene into the school meals for pre-school children. New products should be formulated from solar dried fruits and vegetables.

CHAPTER IV

SENSORY QUALITY OF SWAZI VEGETABLE STEWS PREPARED FROM REHYDRATED SOLAR DRIED VEGETABLES

Phumzile Mdziniso, Margaret J. Hinds, Gail Gates,
Danielle Bellmer, and Barbara Brown

Department of Nutritional Sciences
Oklahoma State University
Stillwater, Oklahoma 74078

ABSTRACT

Vegetable stew mixtures were formulated from solar dried collard greens and carrots based on their β-carotene content, color, texture after rehydration and rehydration ratio. Six stew formulations were prepared. Standard procedures for preparation were based on traditional methods of preparation used in Swaziland. Stews were evaluated for acceptability on a 9-point Hedonic Scale by a panel of 36 untrained African-born consumers. The results showed no significant difference in acceptability of color and overall appearance in all six stews, but the liking of flavor and texture was different. Stew prepared from 100% dried collard greens was liked less in flavor and texture, than the control (100% fresh collard greens) stew. Although panelists were not accustomed to vegetable stews with dehydrated carrots, stews containing a 50:50 ratio of dehydrated carrots to dehydrated collard greens were well accepted by panelists in terms of color, flavor, overall appearance and texture. The mixed vegetable stews were similarly liked to the fresh collard green stew. The frequency of eating vegetable stews in the U.S. or in their native African country did not have a significant effect on the acceptability of color, flavor, overall appearance and texture. Consuming stews prepared from mixtures of dehydrated collard greens and dehydrated carrots increased the beta-carotene intake in the 100% stews that were prepared from green vegetables only.

INTRODUCTION

Increasing the amount of bioavailable micronutrients in plant foods for human consumption is a challenge, which is very important in developing countries. Green leafy and yellow vegetables, such as collard greens and carrots, have been reported to be a major source of dietary vitamin A that is obtained in the form of beta-carotene. Beta-carotene is a major precursor of vitamin A from plant foods that have yellow or orange colors and green leafy vegetables. Gomez (1981) reported that fruits and vegetables constitute the major or sometimes the sole source of vitamin A in many developing countries. He reported that vitamin A adequacy in local diets in Kenya was generally below 60 percent (as a percent of the minimum daily requirement) and could go as low as 3 percent in some areas during the dry season.

Incorporation of beta-carotene rich materials in the daily human diets is considered the most cost-effective approach to the prevention of vitamin A related health problems, which are common in children in developing countries (Dignos *et al.*, 1992*)*. In Swaziland, stews made from green leafy vegetables and groundnut sauce is the most common accompaniment to the staple food, thick maize porridge. The vegetables are affordable and accessible to many people. Despite the availability and easy access, vitamin A deficiency in the diet remains a major health concern. The vitamin A study that was conducted in Swaziland in 1995 confirmed that 46% of children 6-71 months of age, had marginal vitamin A status while 7% had vitamin A deficiency (Swaziland Nutrition Council, 1997). Vitamin A deficiency was attributed to seasonality, and lack of appropriate processing and preservation techniques. The presently used open air sun-drying methods give rise to poor quality dried leaves that are not generally acceptable to consumers when they are rehydrated into stews.

The amount of beta-carotene concentrated after drying varies, depending on the type of vegetable and the processing method. Some vegetables, like amaranth (a green leafy vegetable), have been found to lose more beta-carotene than others. Therefore, blending vegetables that are low in beta-carotene with those higher in beta-carotene could bring about a balance of the beta-carotene (Lakshmi and Vimala, 2000). Dried carrots and yellow-fleshed sweet potatoes have been found to contain more beta-carotene than dried green leafy vegetables (Rock *et al.*, 1998). These yellow vegetables are not presently dried in Swaziland, nor eaten in the traditional vegetable stew. Therefore, the higher beta-carotene vegetables could compensate for the lesser amount of beta-carotene in the leafy vegetable stew. Hence, in this study, vegetable stew mixtures containing dried green and yellow vegetables were formulated to increase the ß-carotene content of the Swazi vegetable stew. This strategy is described by Ruel (2001), as food-to-food fortification where micronutrient dense food is incorporated into preparation of traditional dishes that are poor in micronutrients.

Most dehydrated vegetables are rehydrated in cold water before they are cooked and any rehydration liquid that is unabsorbed is used for cooking the vegetables. This is done to make use of any solutes that may have leached out into the rehydration medium and to enable vegetables to regain their original structure. However, Rahman and Perera (1999) stated that rehydration is not a reversal of the dehydration mechanism but a process that can be difficult and unsatisfactory since changes in the physical properties of the vegetable cell walls occur during dehydration. The final moisture content of the dehydrated vegetable also contributes to the elasticity of the cell wall and its swelling power, which are needed for good rehydration. Mazza (1983) observed that rehydration rate was also affected by treatments applied to vegetables before dehydration. Blanching combined with other treatments such as sucrose was found to impair moisture uptake in carrots. Dehydrated vegetables could also be rehydrated in boiling liquids like soups and that has been reported to speed up soaking time.

The purpose of this study was to improve sensory quality attributes and bioavailability of ß-carotene in Swazi stew traditionally prepared from dried leafy vegetables. This was done by formulating composite stew mixtures from solar dried leafy and yellow succulent vegetables, and determining acceptability of the stews by African-born consumers.

MATERIALS AND METHODS

Selection of Samples

Three types of vegetables, carrots, sweet potato and collard greens were dehydrated using a solar drier. The dehydration procedures were reported in part I of the study. Four treatments were applied to each fresh vegetable type i.e. two thickness dimensions and two packing loads in the solar drier. The dried vegetables were stored at (21-25°C) in polythene bags. Solar dried and fresh vegetable samples were analyzed for alpha, beta and total carotene content at Ralston Laboratory Services (St Louis, MO). Physical properties of the solar dried vegetables viz; color, texture, moisture content after conditioning, water activity and rate of dehydration were tested. Rehydration tests were run for all solar dried vegetable treatments. Texture of the rehydrated carrots and sweet potato was also evaluated. Treatments for stew formulation were selected based on the results of the rehydration tests, carotene analysis and texture of the rehydrated samples. Dehydrated samples with the highest rehydration ratio and beta-carotene content, and rehydrated texture that was most similar to the fresh vegetable were selected for stew preparation.

Rehydration Procedures

Rehydration of vegetables was carried out to determine the treatments that would be used for formulating mixtures for vegetable stews. The stews were to be later evaluated for acceptability. Solar dried vegetables were rehydrated to optimum time in cold deionized water in order to determine rate of rehydration. A sample of 10g from each vegetable treatment was soaked in 300ml-distilled water (Quintero-Ramos et al., 1992). Carrots and sweet potato samples were removed from the water after 5, 6, 7, and 8 hrs, drained, and patted slightly with paper towels and weighed. For collard greens, samples were weighed at 4, 5, 6, and 7hrs. Rehydration ratio was calculated as follows: Rehydration ratio = wt of soaked product / Wt of dehydrated product.

Texture Analysis

The firmness of fully rehydrated carrots and sweet potatoes was also measured in order to identify the appropriate treatment for subsequent stew formulations for sensory evaluation. The xylem was targeted for measuring the hardness of the carrots, and the central starch granules for taking sweet potato measurements. During tests, samples were supported by a 5mm high metal platform with a 5mm aperture to facilitate puncturing of the sample. This support was positioned on top of the TA 95 platform of the texture analyzer. A TA 52 (2mm diameter) Probe was mounted onto the TA. XT2i, Texture Analyzer (Texture Technologies Corp. Scarsdale, New York), and used to measure hardness (g force) of the rehydrated carrots and sweet potatoes. Hardness was interpreted as the maximum force (g) calculated by Texture Expert Exceed Software when the TA 52 Probe traveled a distance of 4 mm into the sample at a speed of 1 mm/sec.

Preparation of Stews

Two treatments of collard greens were selected for stew formulation because vegetables are most commonly consumed as stews in Swaziland. They were treatments S SH (2cm wide strips and 360g/m^2 solar drier load) which had the highest beta carotene content of 19.9mg/100g, and L D (3mm wide strips and 460g/m^2 load) that contained 16.5mg/100g beta carotene (Table1). The fact that green leafy vegetables are the most abundant and accessible to the Swazi people, and these treatments contained the two highest beta-carotene content justified investigation of both dimensions. Also treatment L D is the most economical in terms of preparation time for cutting into strips and large solar drier load. One treatment of carrots LD was selected. Its pre-dried slices had been 5mm thick and were packed at 715g/m^2 load in the solar drier. It contained 15.5mg/100g beta-carotene. No sweet potato treatment was selected because the beta-carotene content of the dehydrated sweet potato was less than the dehydrated collard greens (Table 1).

Table 1

Beta-Carotene Content and Properties of Dried Vegetables Upon Rehydration

Vegetable Type	Treatment Code	Thickness/ Dimension (cm)	Solar Drier Load (g/m$^{2)}$	B-Carotene Content (mg/100g)	Rehydration Ratio (%)	Firmness (g force)
Carrots	S SH	3mm	430	12.92	5.63	5082
	S D	3mm	715	11.87	5.64	4773
	L SH	5mm	430	9.78	5.05	3442
	L D	5mm	715	15.4	5.03	5626
Sweet Potato	S SH	3mm	430	8.32	4.18	928
	S D	3mm	715	6.53	3.88	2308
	L SH	5mm	430	9.2	3.26	1543
	L D	5mm	715	7.35	3.14	3853
Collard Greens	S SH	2cm	360	19.92	4.35	*
	S D	2cm	465	10.53	4.10	*
	L SH	3cm	360	16.35	4.04	*
	L D	3cm	465	16.50	4.14	*

*Collard greens not tested for firmness because their selection for stew preparation was not based on texture of the rehydrated vegetable

Three stews were prepared from composite mixtures of rehydrated collard greens and carrots, and two from collard greens only. One stew was prepared from fresh collard greens and served as the control. The six stew formulations were prepared according to Table 2. Standard formulations and procedures for preparing the stews were developed based on traditional preparation methods used in Swaziland (Appendix 5).

Table 2

Treatment and Ratios of Collard Greens and Carrots used to Prepare Stews

	Collard Greens		Carrots	
Stew No.	**Treatment**	**Quantity (%)**	**Treatment**	**Quantity (%)**
1	Dried S SH	100	-	-
2	Dried L D	100	-	-
3	Fresh	100	-	-
4	Dried S SH	50	Dried L D	50
5	Dried L D	50	Dried L D	50
6	Dried S SH	75	Dried L D	25

L D = (large) 5 mm thickness and 715g/m^2, for carrots, S sh = (small) 2 cm thickness and 360g/m^2 load and 3cm thickness and 465g/m^2 for collard greens.

Sensory Evaluation

Thirty six (36) panelists were recruited from African students and their families at the Oklahoma State University (Appendix 5) after the approval of the Institutional Research Board (IRB) was obtained (Appendix 6). Panelists were selected on the basis of age, gender, familiarity with similar African-based vegetable stews, and use of peanuts in their diet.

A Balanced Completely Randomized Design for 6 stews was used during sensory evaluation. This meant that all stews appeared in each serving sequence an equal number of times, and that each stew was evaluated an equal number of times before and after every other stew (Appendix 5). Stews were served in Monadic Sequential Order such that each sample stew was served with its questionnaire (Appendix 5), and was collected at the end of each sample evaluation before the panelist was served with the subsequent sample. The stew samples and panelists were identified by a numerical 3-digit code, and panelists were involved in an observation and taste test.

All six stews were prepared at the Food & Agricultural Products Research & Technology Center's Test Kitchen, Oklahoma State University, Stillwater, Oklahoma 74078. Using standard procedures for Affective Sensory Testing (Stone and Sidel, 1992), 36 untrained African-born consumer panelists were asked to evaluate the sensory attributes of color, overall appearance, flavor and texture of the six stews using a 9-point Hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 =like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely). Panelists were requested to respond to some demographic questions of gender, frequency of consumption of vegetables stews when they live in the United States and in Africa to determine if the consumption pattern had an influence on the degree of liking of the stew attributes. They were also asked to indicate consumption intent on a 5- point scale to see if they would eat the stew products if they were available. The results provided information on potential acceptability of the stews by Swazi people.

Data Analysis

To determine acceptability of attributes between the six types of stews, data obtained was analyzed by the GLM Procedure, and multiple range tests – Fisher's LSD were used to compare stews. The SAS Computer Package, version 8.1 for Microsoft Windows, was used for all data analysis.

Results and Discussion

Of the 36 panelists who took part in the sensory evaluation, 20 were males and 16 were females. Twenty-seven of the panelists consumed vegetable stews more than 8 times/month when they were home in Africa, and 24 panelists still consumed the vegetable stews more than 4 times/month here in the US. A higher number of panelists, 83–92%, expressed their intent for consuming stews 3, 4, 5, and 6 if available. These stews were prepared from fresh collard greens, 50% dried greens to 50% dried carrots and 75% dried greens to 25% dried carrots, respectively. This showed that formulated stew mixtures from solar dried vegetables were all considered good. Only one person was not sure whether they would eat the stew made with fresh collard greens whilst 2 persons would definitely not eat. It was interesting to observe that the new stew formulations with carrots were liked similarly to the control stew, which was prepared from fresh collard greens (Table 3). Table 4 shows the mean scores of the sensory attributes of all six vegetable stews as evaluated by male and female panelists. Panelists liked all stews slightly or moderately. This is confirmed by the mean scores, which ranged from 6-8. Gender had no influence on the acceptability of the color, overall appearance, flavor and texture in all the six stews.

Table 3

Frequency of Consumption Intent for the Six Stews

Stew Type	Definitely Would Not Eat	May or May Not Eat	Definitely Would Eat
1	4	4	28
2	3	8	25
3	2	1	33
4	0	4	32
5	1	2	33
6	1	5	30

Total no. of panelist = 36
1=100% dried greens (S SH)
2=100% dried greens (L D)
3= fresh collard green only (control)
4=50% carrots (L D): 50% dried collard greens (S SH)
5=50% carrots (L D): 50% dried collard greens (L D)
6=25% carrots (L D): 75% dried collard greens (S SH)

Color

The study found no significant difference (p = 0.9729) in the liking of color among all six stews (Table 4). Mean scores showed that panelists liked the color of the stews slightly to moderately. The acceptability of the green color might have been a result of the steam-blanching treatment as Badifu *et al.* (1995) found that steamed blanched green vegetables gave a pale green color that was acceptable to the panelists. Responses to the multi-colored stews suggest that African-born panelists would accept color of multi-colored stews.

Table 4

Overall Mean Scores for Sensory Evaluation of Vegetable Stews by Male and Female Panelists

Type of Stew	Color *	Overall Appearance *	Flavor *	Texture *	Consumption Interest **	Freq. of Eating Stews in US	Freq. of Eating Stews in Africa
1	6.6 ± 1.84a	6.4 ± 1.99a	6.9 ± 1.97 c	6.6 ± 1.89b	4.0 ± 1.03b	1.7 ± 0.45a	1.8 ± 0.45a
2	6.6 ± 1.81a	6.7 ± 1.90a	7.1 ± 1.86bc	7.0 ± 1.96ab	4.1 ± 1.18ab	1.7 ± 0.48a	1.8 ± 0.44a
3	6.9 ± 1.69a	6.7 ± 1.51a	7.6 ± 1.51ab	7.9 ± 1.0a	4.6 ± 0.80a	1.7 ± 0.48a	1.8 ± 0.42a
4	6.8 ± 2.01a	6.9 ± 1.99a	8.1 ± 0.83a	7.5 ± 1.44ab	4.5 ± 0.70ab	1.7 ± 0.48a	1.8 ± 0.42a
5	6.7 ± 1.85a	6.8 ± 1.86a	7.9 ± 0.97a	7.8 ± 1.44a	4.6 ± 0.73ab	1.7 ± 0.48a	1.8 ± 0.44a
6	6.9 ± 1.62a	6.8 ± 1.77a	7.5 ± 1.58ab	7.4 ± 1.33ab	4.3 ± 0.91ab	1.7 ± 0.48a	1.8 ± 0.44a

Means for a particular attribute, in the same column, followed by the same letter are not significantly different at $\alpha = 0.05$ (Fisher LSD Test).

1 = 100% dried greens (S SH)
2 = 100% dried greens (L D)
3 = fresh collard green only (control)
4 = 50% carrots (L D): 50% dried collard greens (S SH)
5 = 50% carrots (L D): 50% dried collard greens (L D)
6 = 25% carrots (L D): 75% dried collard greens (S SH)

*Evaluated on a 9 – point Hedonic Scale: 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, .9 = like extremely.

** Evaluated on a 5 – point Scale: 1 = Definitely would not eat, 2 = probably would not eat, 3 = May or May not eat, 4 = probably would eat, 5 =Definitely would eat.

Appearance

Stew type did not significantly (p = 0.8799) affect the degree of liking for the overall appearance of the stews (Table 4). Mean scores for this attribute ranged from 6.4 ± 1.99 in stew 1 to 6.9 ± 1.99 in stew 4 indicating that overall appearance was liked slightly to moderately. The overall appearance of the 50% collard greens and 50% carrots in stews 4, 5 and the 75% collard greens and 25% carrots in stew 6, gained slightly higher, (though not significant) than the control which the panelists are accustomed to consuming.

Flavor

The degree of liking for flavor was significantly different among the stews p = 0.0049. The 50:50 stews 4 and 5 showed that panelists liked the flavor of the stews very much. The magnitude of the standard deviation also confirms that the means are a good representation of the scores for the two stews. The flavor of the 100% dried collard greens, stew 1 from treatment S SH, was the least liked and was only similar in flavor to stew 2 prepared from 100% collard greens from treatment L D, but was different from all the stews cooked from mixed vegetables and the control.

Texture

There was a significant difference (p = 0.0045) in the liking of texture among the stews. The mean scores for texture ranged from 6.6 ± 1.97 to 7.9 ± 1.00 (Table 4). The 50:50 and 75:25 ratios, stews 4, 5 and 6 had texture that was liked moderately, and were equally liked (p>0.05) to the control, stew 3. The texture of the control and stew 5 were almost liked very much (7.9 ± 1.0 and 7.8 ± 1.44), respectively. The stew prepared from 100% dried collard greens, stews 1, was the least liked stew in texture.

Influence of Demographic Variables

Panelist's gender did not significantly ($p > 0.1$) affect degree of liking of the sensory attributes of the stews. There was no correlation between frequencies of consumption of vegetable stews here in the United States and acceptability of color, flavor, overall appearance and texture of the stews. No correlation between frequency of consumption in Africa and acceptability of color, flavor and overall appearance, and a slight –ve correlation with texture acceptability. In Africa the stews are cooked for a longer time until they are soft but the experimental stews had more firm texture and that might explain the trend that was observed.

Consumption Interest

Between 83 to 92% of the panelists showed interest in consuming stews that were prepared from 50: 50 and 75: 25 ratios of dehydrated collard greens to dehydrated carrots. Panelists found these stews similar in their attributes to the stew prepared from fresh collard greens (control). Four (4) panelists were sure that they would definitely not eat the stew prepared from100% dried collard greens from treatment S SH (stew 1) whilst 8 panelists were not sure whether they would eat or not the stew prepared from the other 100% dried greens from treatment L D (stew 2).

Beta-Carotene Content in the Stews

According to the FAO standards for developing countries, children from 1 to 10 yrs need 400μg Retinol per day to prevent deficiency diseases and for growth, health and maintain ace of the body. Table 5 shows the amount of beta-carotene that could be provided if people consumed the vegetable stews that were evaluated for acceptability. The 100% stew prepared from 15g of the dehydrated collard greens only would provide 200μg beta-carotene, while the 75: 25 ratio of dehydrated collard greens and dehydrated carrots would provide 450μg beta-carotene and the 50:50% would provide 510μg (Table 5). When the beta-carotene is converted to Retinol Equivalents it becomes small that eating the stews only would not meet the daily intake. However, mixing greens and orange vegetables would increase the beta-carotene intake in the 100% stew by 250 to 310μg. per adult serving (Table 5). The formulated stews prepared from dehydrated greens and dehydrated carrots were liked slightly to moderately for all their attributes. Hence their consumption should be encouraged as they can increase the amount of beta-carotene in the traditional stews that are normally prepared from dried green leafy vegetables only.

Table 5

Beta-Carotene Content in the Formulated Stews

Stew Type	Quantity of Vegetable	Amount of β-Carotene (mg/100g)	Amount of β-Carotene (μg/100g)
50:50	15g collard greens	0.20	200
	15g carrots	0.31	310
75:25	22.5g collard greens	0.29	290
	7.5g carrots	0.16	160
100%	15g collard greens	0.20	200

100%= dried greens (S SH, L D)
50% =50% dried collard greens (S SH, LD): carrots (L D)
75% dried collard greens (S SH, LD): 25% carrots (L D)

Conclusion

Even though dehydrated carrots are not eaten in the traditional stew, the 50%dried collard greens to 50% dried collard greens to carrots stews were the most acceptable stews in terms of color, flavor, texture and overall appearance. Incorporating carrots to the traditional Swazi stew that is prepared from dried leafy vegetables only, can improve color, flavor, texture and overall appearance of the stew. It can also improve beta-carotene content, bioavailability of beta-carotene and provide variety in the traditional stew. Both collard green treatments were similarly acceptable when made into stews. This indicates that solar drier load (360g/m^2 vs 465g/m^2 and strip width of vegetables (2cm vs 3cm) did not adversely affect sensory quality of the dried vegetables. That is an advantage in that the most economical method of dehydration for collard greens (3cm thickness and 465g/m^2 could be used knowing that sensory quality attributes of their stews will be acceptable to consumers. With a surplus of carrots during their season, they could be dried economically, and used profitably with the stews.

Recommendations

1. Collard greens cut into 3cm wide strips and packed into 465g/m^2 may be used to obtain dehydrated greens for making acceptable stews.
2. Stews made from 50:50 ratio of dried carrots and dried collard greens could be used to provide high beta-carotene and as alternative to the traditional stews made from dried green leafy vegetables only.

3. Solar dried carrots and sweet potatoes could be incorporated into the traditional weaning food (thin porridge) to provide β-carotene and increase the nutritional density of the monotonous baby food.

Future Research

Determine acceptability of new products, formulated from other types of solar dried vegetables and fruits, by Swazi consumers.

REFERENCES

1. Allen H.L. and Gillespie, R.S. (2001). What Works? A Review of the Efficacy and Effectiveness of Nutrition Interventions. Administrative Committee on Coordination / Sub-Committee on Nutrition (ACC /SCN). 61-67.

2. Badifu G.I.O., Akpapunam M.A. and Mgebemere V.M. (1995). The Fate of Beta-carotene in Processed Leaves of Fluted Pumpkin (*Telfairia occidentalis Hook.f.*): A Popular Vegetable in Nigerian Diet. Plant Foods for Human Nutrition 48:141-147.

3. Balochi A.K., Buckle K.A. and Edwards R.A. (1977). Effects of Processing Variables on the Quality of Dehydrated Carrot. Journal of Food Technology. 1977: 12: 295-307.

4. Booth S.L, Johns T. and Kuhnlein V. (1992). Natural Food Sources of Vitamin A and Provitamin A. Food and Nutrition Bulletin 14: 6-35.

5. Dignos R.L., Cerna P.F. and Truong V.D. (1992). Beta-Carotene Content of Sweet Potato and Its Processed Products.ASEAN Food Journal 7: (3): 163-166.

6. Esper A. and Muhlbauer W. (1998). Solar Drying – An Effective Means of Food Preservation. Renewable Energy. (15): 95–100.

7. Gomez M. I. (1981). Carotene Content of Some Green Leafy Vegetables of Kenya and Effects of Dehydration and Storage on Carotene Retention. Journal of Plant Foods 3: 231-244.

8. Groff J.L. and Gropper S.S. (1999). Advanced Nutrition and Human Metabolism. Wadsworth/Thomson Learning, Belmont, US.

9. Hudelson P.; Dzikunu H.; Mensah J.D.; Morris S.; Arthur P.; and Kirkwood B. (1999). Dietary Patterns in a Rural Area of Ghana and Their Relevance to Vitamin Consumption. Ecology of Food and Nutrition. 38:183-207.

10. IVACG Report on the International Vitamin A Consultative Group. (1999). The Bioavailability of Dietary Carotenoids: Current Concepts. International Life Sciences Institute. Research Foundation, Washington DC. USA.

11. Lakshmi B. Vimala V. (2000). Nutritive Value of Dehydrated Green Leafy Vegetable Powders. Journal Food Science Technology 2000, 37 (5): 465 -471

12. Luh B.S., Somogyi L.P. and Meehan J.J. (1975). Vegetable Dehydration. AVI Publishing Company, Inc., Westport, Connecticut.

13. Luh B.S. and Woodroof J.G. (1975). Dehydration of Vegetables. McGraw – Hill Publications. R. A. Brink, Consulting Editor.

14. Maeda E.E and Salunkhe D.K. (1981). Retention of Ascorbic Acid and Total Carotene in Solar Dried Vegetables. Journal of Food Science: 46: 1288-1290.

15. Maharaj V. and Sankat C.K. (2000). The Rehydration Characteristics and Quality of Dehydrated Dasheen Leaves. Canadian Agricultural Engineering. 42, (2): 81-85.

16. Mazza G. (1983). Dehydration of Carrots. Effects of Pre-treatments on Moisture Transport and Product Quality. Journal of Food Technology. 19: 113-123.

17. McWilliams M. (2001). Foods *Experimental Perspectives.* Prentice Hall, Upper Saddle River, New Jersey.

18. Mosha T.C., Page R.D., Adeyeye S., Laswai H.S. and Mtebe K. (1997) Effects of Traditional Practices on the Content of Total Carotenoids, Beta-carotene, Alpha-carotene and Vitamin A Activity of Selected Tanzanian Vegetables. Plant Foods for Human Nutrition.50:189-201.

19. Nalubola R. and Nestel P. (1999). The Effects of Vitamin A Nutriture on Health: A Review. International Life Sciences Institute, Washington D.C.

20. Ncube T.N., Greiner T., Malaba L.C. and Gebre-Mehin M. (2001). Supplementing Lactating Women With Pureed Papaya and Grated Carrots Improved Vitamin A Status in a Placebo-Controlled Trial. Journal of Clinical Nutrition 131: 1497-1502.

21. Negi P.S. and Roy S.K. (2000). Effects of Blanching and Drying on Beta-carotene, Ascorbic acid and Chlorophyll Retention of Leafy Vegetables. Journal of Food Technology, 33 (4): 295-298.

22. Onayemi O. and Badifu G.I.O. (1987). Effects of Blanching and Drying Methods on the Nutritional and Sensory Quality of Leafy Vegetables. Plant Foods for Human Nutrition: 37:291-298.

23. Premavalli K.S., Majumdar T.K. and Madhura C.V. (2001). Processing Effect on Color and Vitamins of Green Leafy Vegetables. Journal of Food Science and Technology 38: (1): 79-81.

24. Quintero-Ramos A., Bourne M.C. and Anzaldua-Morales A. (1992). Texture and Rehydration of Dehydrated Carrots as Affected by Low Temperature Blanching. Journal of Food Science. 57 (5): 1127 –1139.

25. Rahman S.M. and Perera C.O. (1999) Drying and Food Preservation. Food Science Technology. 94: 173-216.

26. Rock C.L, Lovalvo J.L, Emenhiser C. and Ruffin M.T. (1998). Bioavailability is Lower in Raw than in Processed Carrots and Spinach in Women. Journal of Nutrition. 913.

27. Ruel M.T. and Levin C.E. (2000). Assessing the Potential for Food-Based Strategies to Reduce Vitamin A and Iron Deficiencies: A Review of Recent Evidence. International Food Policy Research Institute, Washington D. C.

28. Ruel M.T. (2001). Can Food Based Strategies Help Reduce Vitamin A Deficiencies? International Food Policy Research Institute, Washington DC.

29. Semba R.D., Miotti P.G., Chiphangwi J.D., Dallabetta G., Yang L., Saah A. and Hoover D. (1998). Maternal Vitamin A Deficiency and Infant Mortality in Malawi. Journal of Tropical Pediatrics, 44: 232-234.

30. Stone H. and Sidel J.L. (1992). Sensory Evaluation Practices.Tragon Corporation, Redwood City, CA. Chapter 4 and 7.

31. Swaziland Government (1997). Annual Statistical Bulletin. Central Statistical Office. Mbabane. Swaziland.

32. Swaziland Nutrition Council, (1997). Nutrition News. Mbabane, Swaziland.

33. Tomkins A. Improving Nutrition in Developing Countries Can Primary Care Help? Journal of Tropical Medicine 38: 226-232.

34. ULOG, (1998). The Solar Cooking News. www.ulog.ch/english/u_dry.html.

35. USDA Table of Nutrient Retention Factors Release 4 (1998). USDA-NCC Carotenoid Database for U.S. Foods.

36. VanGarde S. and Woodburn M. (1994). Food Preservation and Safety: Principles and Practice. Iowa University Press, Ames, Iowa.

37. Yadav S.K. and Sehgal S. (1995). Effect of Home Processing on Ascorbic Acid and Beta-carotene Content of Spinach (Spinacia oleracia) and Amaranth (*Amaranthus* tricolor) Leaves. Plant Foods for Human Nutrition 47:125-131.

APPENDIXES

APPENDIX 1

PRE-PROCESSING OPERATIONS

TABLE 1

Blanching Time Established from Results of Peroxidase Test for Collard Greens, Carrots and Sweet Potatoes

		Time (min)			
Vegetable Type	**Thickness**	**1.5**	**2.0**	**3.0**	**3.5**
Carrots	3 mm		X		
	5 mm		X		
Sweet Potato	3 mm			X	
	5 mm				X
Collard Greens	2 cm	X			
	3 cm		X		

APPENDIX 2

PEROXIDASE TEST

PEROXIDASE TEST

10g sample of blanched material

Guaiacol solution

Hydrogen peroxide

Distilled water

PROCEDURE

1. cut into small pieces and place in a mortar with small sand.
2. add sufficient water to give the best consistency for though maceration.
3. grind for 3 min.
4. add more water so that the total water added is 30ml.
5. mix thoroughly.
6. filter mixture through cotton gauze (cheese cloth).
7. add 2 mls filtrate to 20 mls distilled water in test tube.
8. add 1 ml 0.5% guaiacol solution and 0.08%hydrogen peroxide without mixing.
9. mix contents thoroughly by inverting the tube and note color development.
10. if a pink color develops within 3.5 min then enzymes are not inactivated, vegetables need to be steam blanched for longer time.

APPENDIX 3

TABULATED RESULTS

TABLE 1

Dehydration Rate, Drying Time and Product Yield for Replication 1

Vegetable/ Thickness Rep: 1	Wt of Original Sample (kg)	Wt of Dried Sample (kg)	Final Moisture Content (%)	Dehydration Rate (%)	Drying Time (hrs)	Drying Temperature	Percent Yield (%)
Carrots (3mm)							
Smaller depth	4.8 kg	0.59	8.6	3.47	12	34-45	12.29
Deep depth	8.0 kg	0.90	6.08	3.73	10	30-42	11.25
5mm							
Smaller depth	4.8 kg	0.86	10.68	2.97	14	25-44	17.92
Deep depth	8.0 kg	1.04	7.96	3.26	10	32-45	13.00
Sweet Potatoes (3mm)							
Smaller depth	4.8 kg	0.92	10.24	3.65	13	29-42	19.17
Deep depth	8.0 kg	1.34	7.45	2.68	16	28-39	16.75
5mm							
Smaller depth	4.8 kg	0.86	8.13	3.60	12	30-46	17.06
Deep depth	8.0 kg	1.54	8.91	3.49	14	31-50	19.25
Collard Greens (2cm)							
Smaller depth	4.0 kg	0.42	8.00	6.44	8	30-39	10.5
Deep depth	5.2 kg	0.54	4.24	5.60	10	27-39	10.39
3cm							
Smaller depth	4.0 kg	0.40	7.26	5.53	10	32-40	10.00
Deep depth	5.2 kg	0.50	8.33	4.83	10	31-40	9.62

TABLE 2

Dehydration Rate, Drying Time and Product Yield for Replication 2

Vegetable/ Thickness Rep: 2	Wt of Original Sample (kg)	Wt of Dried Sample (kg)	Final Moisture Content (%)	Dehydration Rate (%)	Dehydration Time	Drying Temperature	Percent Yield (%)
Carrots (3mm)							
Smaller depth	4.8 kg	0.72	4.67	2.97	8	30-50	15
Deep depth	8.0 kg	1.03	7.65	2.79	10	26-43	12.88
5mm							
Smaller depth	4.8 kg	0.78	6.04	3.76	8	35-48	16.25
Deep depth	8.0 kg	1.17	6.73	2.79	10	31-48	14.63
Sweet Potatoes (3mm)							
Smaller depth	4.8 kg	0.99	7.79	4.04	10	28-45	20.63
Deep depth	8.0 kg	1.56	7.20	3.88	12	27-48	19.5
5mm							
Smaller depth	4.8 kg	1.07	7.89	4.72	11	29-45	22.29
Deep depth	8.0 kg	1.75	7.94	3.17	14	27-47	21.88
Collard Greens (2cm)							
Smaller depth	4.0 kg	0.23	6.22	6.24	8	34-43	5.75
Deep depth	5.2 kg	0.46	7.25	5.33	10	39-43	8.85
(3cm)							
Smaller depth	4.0 kg	0.46	4.32	6.80	8	29-42	11.00
Deep depth	5.2 kg	0.53	5.84	6.50	9	36-43	10.19

TABLE 3

Moisture β-Carotene Content in Fresh and Dehydrated Vegetables

Vegetable Type and Treatment	Initial Moisture (%)	Final Moisture (%)	B-Carotene Content (mg/100g) in Wet Weight Basis	
			Fresh	Dehydrated
Carrots				
S SH	56.3	8.76	3.07	12.9
S D	50.2	7.00	3.07	11.9
L SH	65	8.75	3.07	9.8
L D	54.1	8	3.07	15.5
Sweet Potato				
S SH	58.2	10.0	2.35	8.32
S D	53.7	8.0	2.35	6.53
L SH	61.37	9.0	2.35	9.2
L D	72.3	11.0	2.35	7.35
Collard Greens				
S SH	64.00	7.0	2.36	19.9
S D	63.6	7.7	2.36	10.5
L SH	62.1	7.3	2.36	16.4
L D	61.9	7.9	2.36	16.5

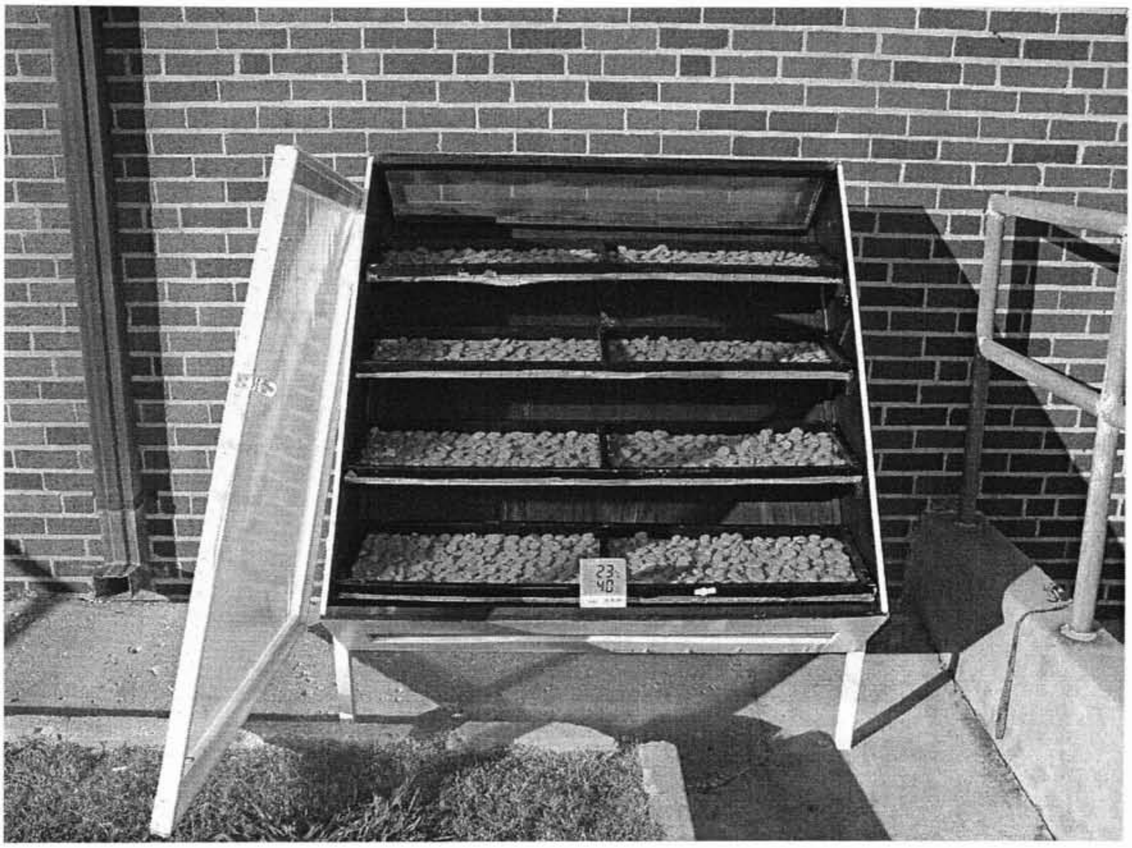
S SH = (small) 3mm thickness and 430g/m^{2}load, L SH = (large) 5mm thickness and 430g/m^{2}load, L D = (large) 5mm thickness and 715g/m^{2}load, S D = (small) 3mm thickness and 715g/m^{2}load (For carrots and sweet potatoes).

S SH = (small) 2cm thickness and 360g/m^{2}load, L SH = (large) 5mm thickness and 360g/m^{2}load, L D = (large) 5mm thickness and 465g/m^{2}load, S D = (small) 3mm thickness and 465g/m^{2}load (For collard greens).

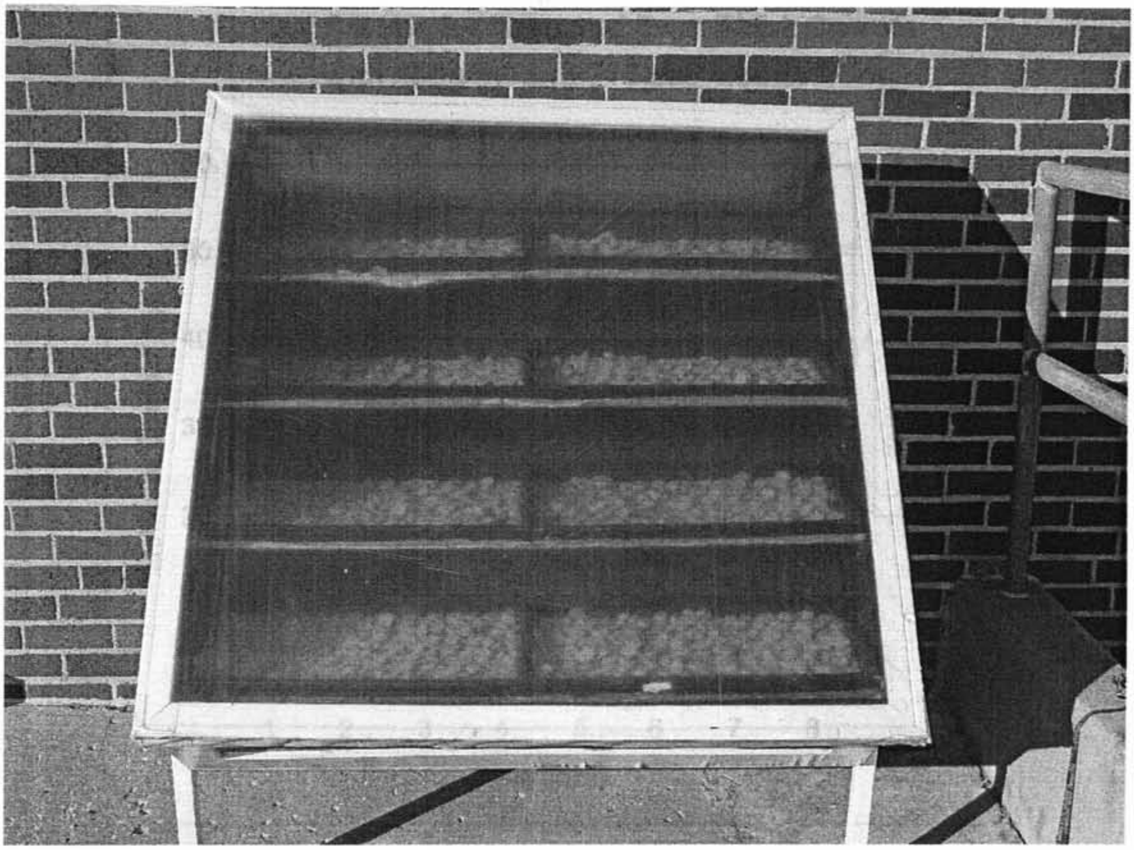
APPENDIX 4

SOLAR DEHYDRATION

SOLAR DRIER WITH FOUR TRAYS



SOLAR DRIER WITH COVER



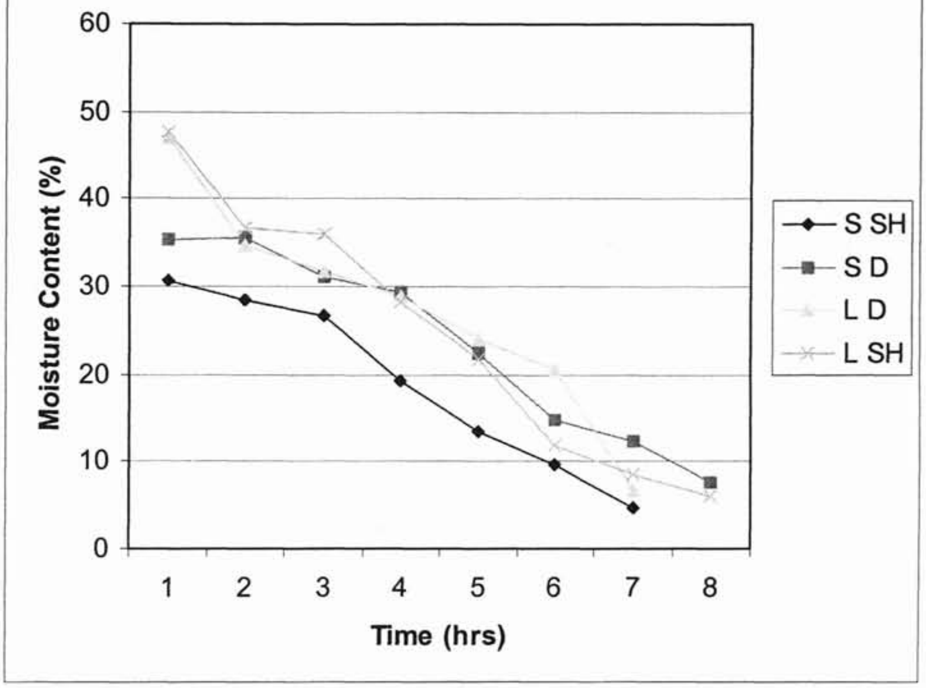


Figure 1
Drying Curves for 3mm and 5mm Thick Carrots with 460g/m^2 and 715g/m^2 Loads

Figure 2
Drying Curves for 3mm and 5mm Thickness
Sweet Potato and 460g/m^2 and 715g/m^2 Loads

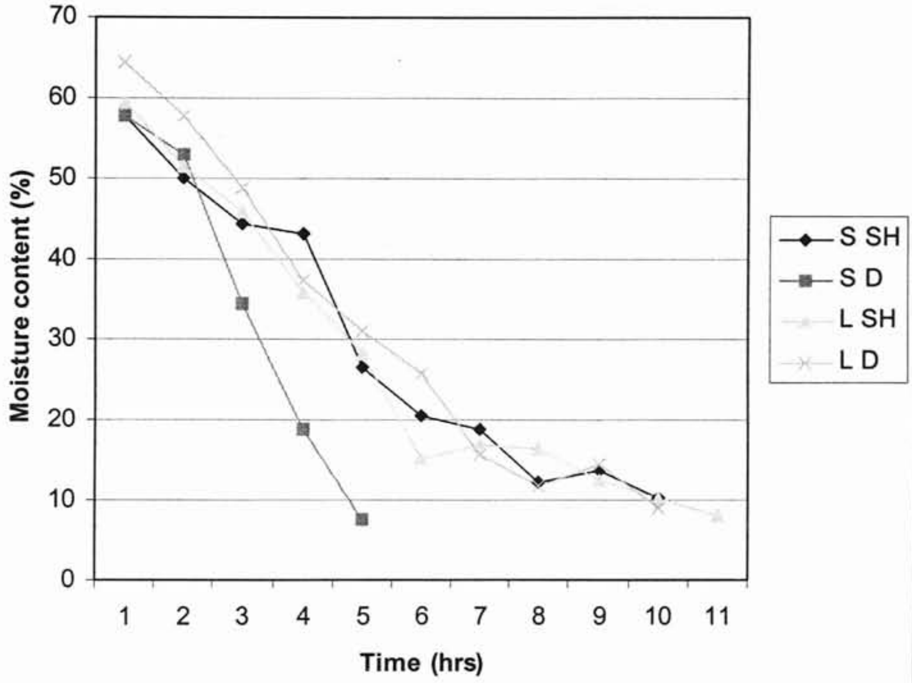
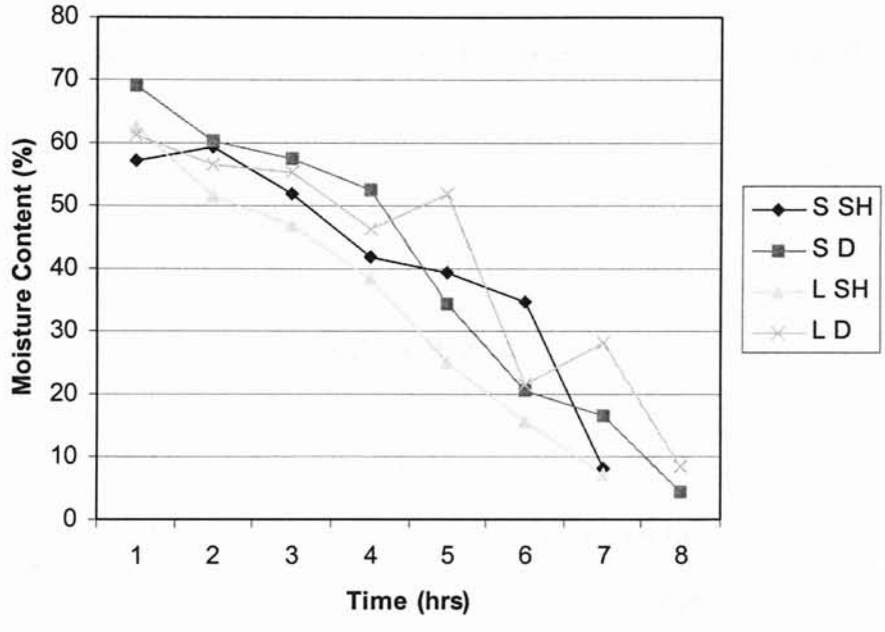


Figure 3
Drying Curves for Collard Greens, 2cm and 3cm Thickness and 360g/m^2 and 465g/m^2 Loads



Experimental Design for Solar Dehydration

Random Assignment of Vegetables to Treatment

Vegetable code	Width code	Depth code
Carrots = **O**	Small= **S**	shallow= **sh**
S/potatoes= **Y** Collard greens= **G**	Large= **L**	deep= **D**

Process Rep 1

	wk 1	**wk 2**	**wk 3**	**wk 4**
Monday	G L sh **(058)**	O L sh **(248)**	Y L D**(568)**	G L D **(726)**
Wednes	O S sh **(141)**	O S D **(534)**	G S D **(623)**	Y S sh **(813)**
Friday	Y L sh **(187)**	O L D **(535)**	Y S D **(706)**	G S sh **(843)**

Process Rep 2

Monday	Y S D **(069)**	G S D **(368)**	O S D **(465)**	Y L sh **(729)**
Wednesday	G S SH **(143)**	Y S SH **(399)**	O L SH **(483)**	O L D **(919)**
Friday	O S SH **(150)**	G L D **(409)**	G L SH **(695)**	Y L D **(930)**

APPENDIX 5

SENSORY EVALUATION

CONSENT FORM

RESEARCH PROJECT TITLE: Determining acceptability of six types of vegetable stews.

A. AUTHORIZATION

I, ______________________________, hereby authorize Dr Margaret J Hinds or Phumzile Mdziniso or assistants of her choosing, to use the data from the questionnaire of my evaluation of stews prepared from composite mixtures of rehydrated green leafy and yellow succulent vegetables.

B. DESCRIPTION

The purpose of the research is to evaluate the consumer acceptance of vegetable stews prepared from composite rehydrated mixtures of dried green leafy and yellow succulent vegetables.

Six types of stews will be prepared from composite mixtures of rehydrated green leafy and yellow vegetables. These vegetables have been dried and stored at the Physical and Functional Properties Laboratory 001, HES, Oklahoma State University. Panelists will be involved in an observation and taste test. They will be presented with 6 types of stews served in a monadic sequential order. A questionnaire will be provided with each sample and will be collected at the end of each sample evaluation before the panelist is served with the next sample. Each sample stew will be identified by a numerical code and panelists will be asked to observe and taste the sample and answer the questions asked in the questionnaire. When the final sample has been evaluated, the final questionnaire will be collected and panelists can leave the testing room.

All stews will be prepared at the Food & Agricultural Products Research Technology Center. The stews contain carrots, sweet potato, collard greens, tomato, spring onions, peanuts, salt and oil. **Individuals who are allergic to carrots, sweet potato, collard greens, tomato, spring onions, peanuts, salt and oil or who do not wish to consume them, may not participate in the evaluation**. Otherwise there are no foreseeable risks involved in participating in the evaluation.

One benefit of participating in this consumer acceptability test will be your familiarity with a taste panel process. Another benefit will be the opportunity to learn about the new vegetable stews that could increase the choices of β-carotene rich products that may be in the African consumer market in the future.

The responses from this study will be tabulated as a group and names of panelists will not be used. The principal investigator will store the consent forms of the panelists for one year before they will be destroyed. Information from the questionnaires will be transferred to a database and no names will be attached to the responses. Any data or scientific papers published from this study will not identify individual panelists.

For more information about the research contact Dr Margaret J. Hinds at Room 309 HES (south wing), Oklahoma State University, Stillwater, OK 740 45.Phone☹405- 744-5043. For additional information contact, Sharon Bacher, IRB Executive Secretary, Oklahoma State University, 415 Whitehurst, Stillwater, OK 74078. Phone 405-744-5700.

C. VOLUNTARY PARTICIPATION

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time without penalty after I notify the project director.

D. CONSENT

I have read and fully understood the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ____________________ Time: ____________________

Signed____________________

Signature of Witness: ____

I certify that I have personally explained all elements of this form to the subject and his/her representative before requesting the subject or his/her representative to sign it.

Signed: ____

Project director or authorized representative

SOLICITATION FORM

From: phumzil@okstate.edu

To:

Date: September 19th, 2002

Sensory evaluation of vegetable stews

I will be conducting sensory evaluation for my thesis on the 3rd and 4th October 2002 at the Food Agricultural Products and Technology Center. The product that you are requested to evaluate will be typical African vegetable stews. Testing will involve observation and tasting of the stews. There will be 6 types of stews to be evaluated and that will take about 1 hour of your time. The stews will contain carrots, collard greens, sweet potato, peanuts, salt, spring onions and tomato.

There will be three testing sessions, at **10.30 am, 12.00 noon and 1.30 pm,** from which you can choose to suit your schedule. Please email me at phumzil@okstate.edu to inform me of 2 possible time sessions that you will be able to attend. After your response I will contact you again for more details on the evaluation process.

Your participation in this study is highly appreciated. If you have any questions, please do not hesitate to ask me.

Thank you.

Phumzile Mdziniso

SAMPLE CODE---------------- **PANELIST CODE---------------** **DATE---------**

1. **PLEASE RINSE YOUR MOUTH WITH WATER BEFORE EVALUATING THE SAMPLE**

FOR EACH OF THE FOLLOWING, PLEASE CHECK ONE APPROPRIATE BOX

2. GENDER: ☐ Male ☐ Female

3. NUMBER OF TIMES PER MONTH YOU CURRENTLY EAT VEGETABLE STEW:

☐ 1 or less ☐ 2-4 ☐ 5-8 ☐9 or more

4. NUMBER OF TIMES PER MONTH YOU EAT VEGETABLE STEW WHEN YOU ARE AT HOME IN AFRICA:

☐ 4 or less ☐ 5-8 ☐ 9-12 ☐ 13 or more

5. **Observe the sample** (do not taste yet) and check the box, which best describes your feelings about the following -.

A) COLOR

Like like like like neither like dislike dislike dislike dislike
extremely very much moderatelyslightly nor dislikeslightly moderately very much extremely
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

B) **OVERALL APPEARANCE**

Like like like like neither like dislike dislike dislike dislike
extremely very much moderatelyslightly nor dislikeslightly moderately very much extremely
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

PLEASE TURN OVER TO CONTINUE

6. Eat some of the sample, and as you chew think about how it tastes and feels in your mouth. Then check the box that best describes your feelings about each of the following attributes of the sample.

A) **FLAVOR**

Like like like like neither like dislike dislike dislike dislike
extremely very much moderatelyslightly nor dislikeslightly moderately very much extremely
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

B) **TEXTURE**

Like like like like neither like dislike dislike dislike dislike
extremely very much moderatelyslightly nor dislikeslightly moderately very much extremely
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

7. Please indicate if you would eat this kind of stew if it were available to you

Definitely would eat	Probably would eat	May or may not eat	Probably would not eat	Definitely would not eat
☐	☐	☐	☐	☐

8. PLEASE RINSE YOUR MOUTH WITH WATER.

THANK YOU

Experimental Design for Sensory Evaluation

Panelist & Code	Serving Order *					
1 971	1 848	2 719	3 783	4 514	5 392	6 637
2 723	2 624	3 047	4 697	5 834	6 014	1 984
3 645	3 116	2 696	1 618	4 564	5 222	6 035
4 891	4 058	5 625	6 509	1 398	2 295	3 450
5 134	2 574	3 506	4 054	5 815	6 916	1 684
6 858	1 589	5 182	6 458	2 601	3 485	4 145
7 939	3 169	4 413	5 041	1 725	2 192	6 940
8 125	6 571	1 582	3 897	2 127	4 491	5 142
9 248	5 389	4 749	1 927	3 982	6 453	2 471
10 045	4 963	1 345	2 967	6 764	3 250	5 057
11 082	5 825	6 965	3 084	4 311	1 183	2 171
12 828	3 676	2 342	5 934	6 892	4 627	1 065
13 364	6 539	3 544	2 757	5 022	1 671	4 588
14 964	2 925	6 209	4 956	1 269	5 755	3 920
15 817	4 020	1 063	5 853	2 011	3 495	6 596
16 630	1 242	4 998	6 425	3 160	2 121	5 737
17 541	5 488	2 612	1 839	6 760	4 069	3 824
18 392	6 101	5 710	2 013	4 228	3 502	1 862
19 030	2 010	6 238	5 171	3 336	1 049	4 032
20 470	3 910	1 154	6 978	5 187	4 364	2 882
21 129	1 884	5 595	3 450	2 098	6 985	4 661
22 312	5 894	6 752	1 488	4 556	3 636	2 115
23 714	4 302	5 074	2 596	6 799	1 336	3 409
24 722	2 417	4 048	3 198	1 601	5 093	6 767
26 047	3 951	5 683	1 220	2 713	6 567	4 430
25 269	6 895	2 531	4 520	3 662	1 558	5 812
27 619	1 903	3 080	6 847	5 677	2 549	4 005
28 861	4 540	6 635	2 909	3 210	5 872	1 075
29 537	5 879	2 761	1 099	6 750	4 544	3 343
30 441	6 170	3 198	4 315	1 597	5 720	2 425
31 634	5 657	4 638	6 077	3 178	2 193	1 744
32 306	6 305	1 690	3 386	2 576	4 214	5 343
33 622	1 160	6 538	2 322	4 734	3 298	5 393
34 564	2 705	4 230	5 737	6 735	1 179	3 705
35 488	3 716	1 468	4 739	5 453	2 938	6 656
36 541	4 045	3 040	5 074	1 152	6 698	2 566

* 1, 2, 3, 4, 5, and 6 represent stew treatments

Vegetable Stew in Peanut Sauce

Ratio: 100% (Used for stews 1 & 2)

Ingredients

20g dried collard greens

60g roasted peanut grounded

50g chopped tomato

1-tablespoon vegetable oil

300ml water from soaking vegetables

30g chopped spring onion

30g green pepper

1 teaspoon heaped seasoning (aromat)

Fresh collard greens (Used for stew 3)

140g fresh collard greens

60g roasted peanut grounded

50g chopped tomato

1-tablespoon vegetable oil

300ml water from soaking vegetables

30g chopped spring onion

30g green pepper

1 teaspoon heaped seasoning (aromat)

Ratio: 50:50 (Used for stews 4 & 5)

15g dried carrots

15g dried collard greens

60g roasted peanut grounded

50g chopped tomato

1-tablespoon vegetable oil

300ml water from soaking vegetables

30g chopped spring onion

30g green pepper

1 teaspoon heaped seasoning (aromat)

Ratio: 75:25 (Used for stews 6)

Ingredients

7.5g dried carrots

22.5g dried collard greens

60g roasted peanut grounded

50g chopped tomato

1-tablespoon vegetable oil

300ml water from soaking vegetables

30g chopped spring onion

30g green pepper

1 teaspoon heaped seasoning (aromat)

Procedure

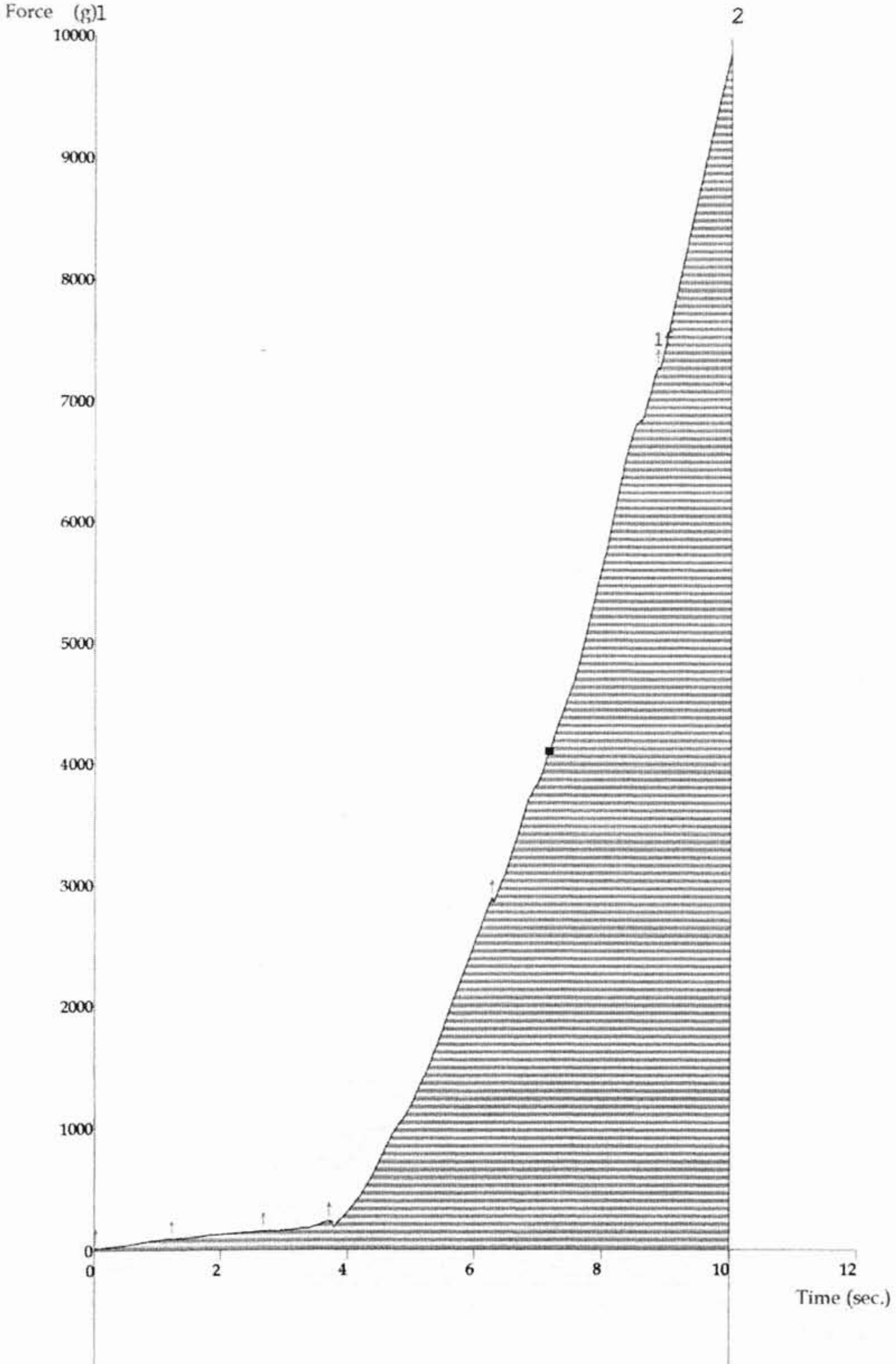
For fresh collard greens, wash leaves thoroughly in plenty clean cold water and cut into 2cm or 3cm thickness. Dried vegetables are cooked after rehydration.

1. **Put first 6 ingredients into a saucepan and bring to boil.**
2. **Let it boil for 17 minutes (Fresh collard greens) or 22min (dried vegetables).**
3. **Add spring onion, g/pepper and seasoning and continue to boil for 3 min.**
4. **Serve.**

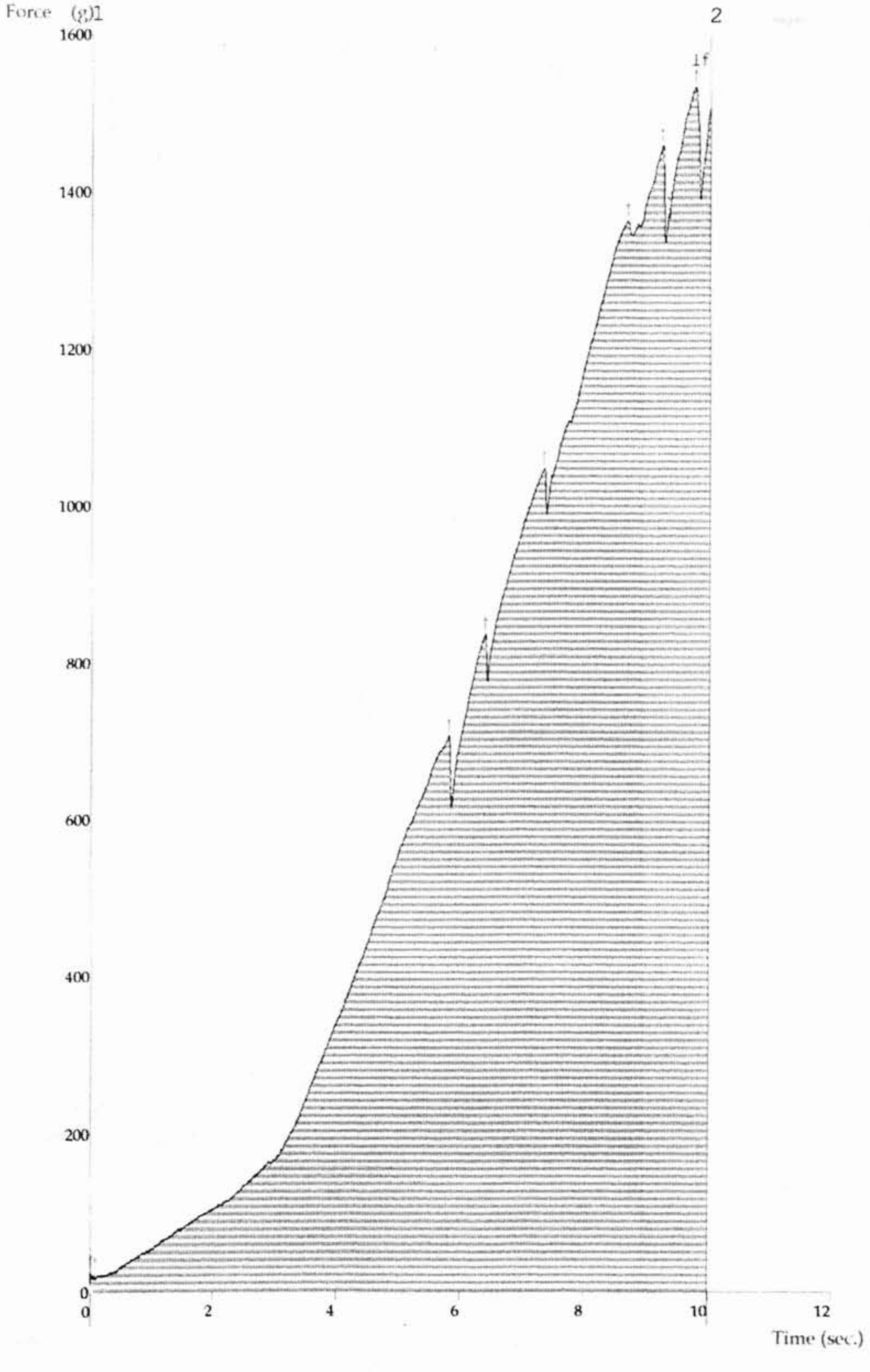
APPENDIX 6

TEXTURE PROFILE GRAPHS

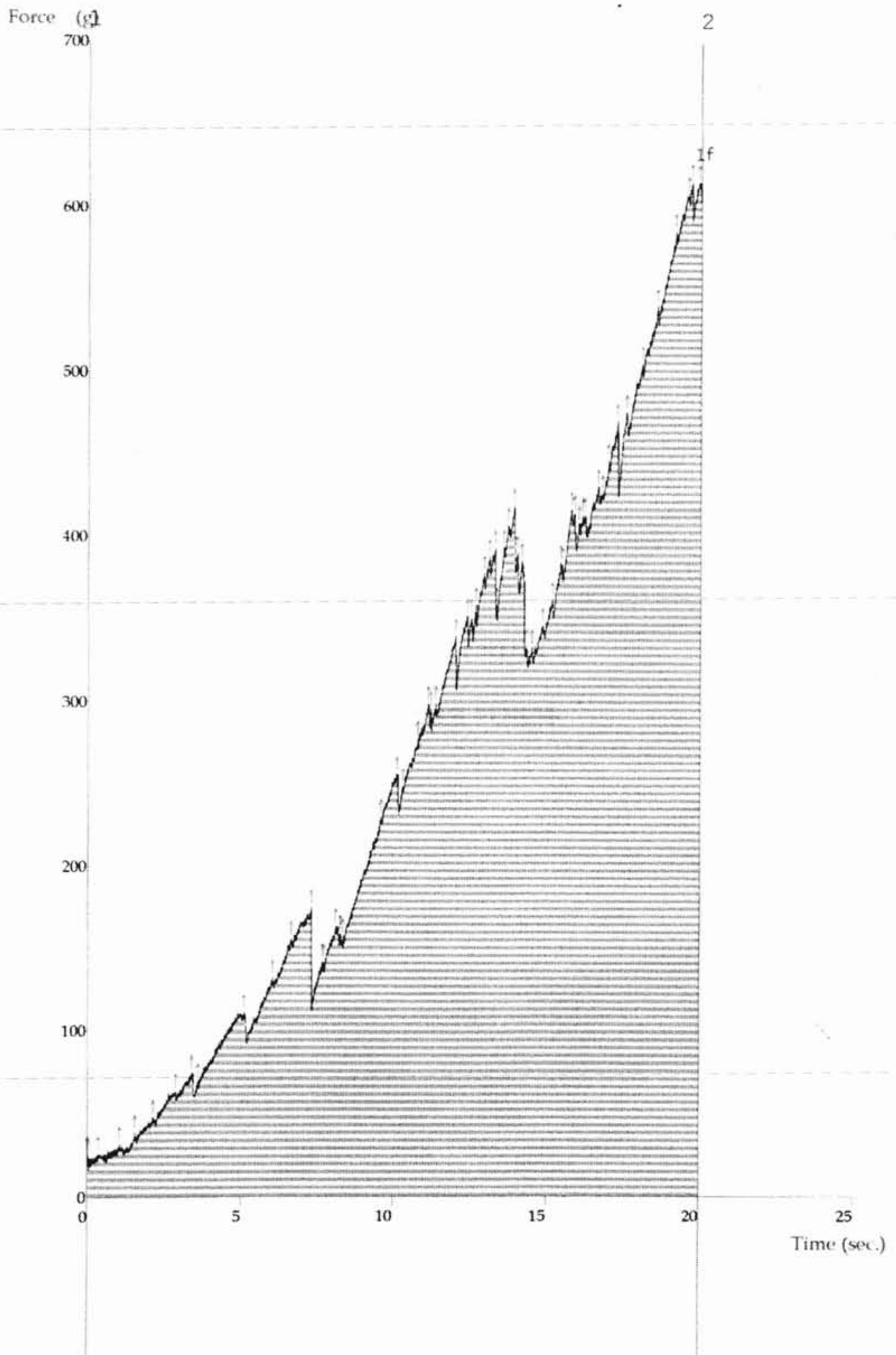
Texture Profile of Dehydrated Carrots



Texture Profile of Dehydrated Sweet Potatoes



Texture Profile of Dehydrated Collard Greens



APPENDIX 7

IRB FORM

Oklahoma State University
Institutional Review Board

Protocol Expires: 9/12/2003

Date: Friday, September 13, 2002 IRB Application No HE0316

Proposal Title: EFFECTS OF SOLAR DRYING ON PHYSICAL AND SENSORY QUALITY, B-CAROTENE CONTENT IN GREEN LEAFY AND YELLOW SUCCULENT VEGETABLES AND COMPOSITE REHYDRATED MIXTURES COMPARABLE TO SWAZILAND MEAL ITEMS

Principal Investigator(s):

Phumzile Mdziniso	Margaret J. Hinds
102 NUP #5	309 HES
Stillwater, OK 74075	Stillwater, OK 74078

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 415 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

Carol Olson

Carol Olson, Chair
Institutional Review Board

VITA

Phumzile Mdziniso

Candidate for the Degree of

Master of Science

Thesis: PHYSICAL AND SENSORY QUALITY, AND β-CAROTENE CONTENT OF SOLAR DRIED VEGETABLES AND REHYDRATED MIXTURES COMPARABLE TO SWAZI VEGETABLE STEWS

Major Field: Nutritional Sciences

Biographical:

Education: Graduated from the University of Swaziland in June 1998 and received a Bachelor of Science Degree in Home Economics. Has participated and attended conferences and short courses, in Swaziland, Tanzania, Kenya, Zimbabwe, Botswana, Israel, and Ireland, on project and business management, Supervisory skills, Counseling, income generation for low-income families and Development of Food Based Dietary Guidelines. Completed the requirements for Master of Science Degree with a major in Nutritional Sciences in Oklahoma State University, in December 2002.

Experience: Has been employed by the Ministry of Agriculture and Cooperatives as assistant home economics officer, responsible for educating rural communities on issues related to nutrition, income generation, home improvement, business and leadership skills (1977 – 1990). Promoted to regional home economic officer from 1991 –2000. Responsibilities included planning, developing, organizing and coordinating regional home economics extension programs.

Professional memberships: Society for Nutrition Education.