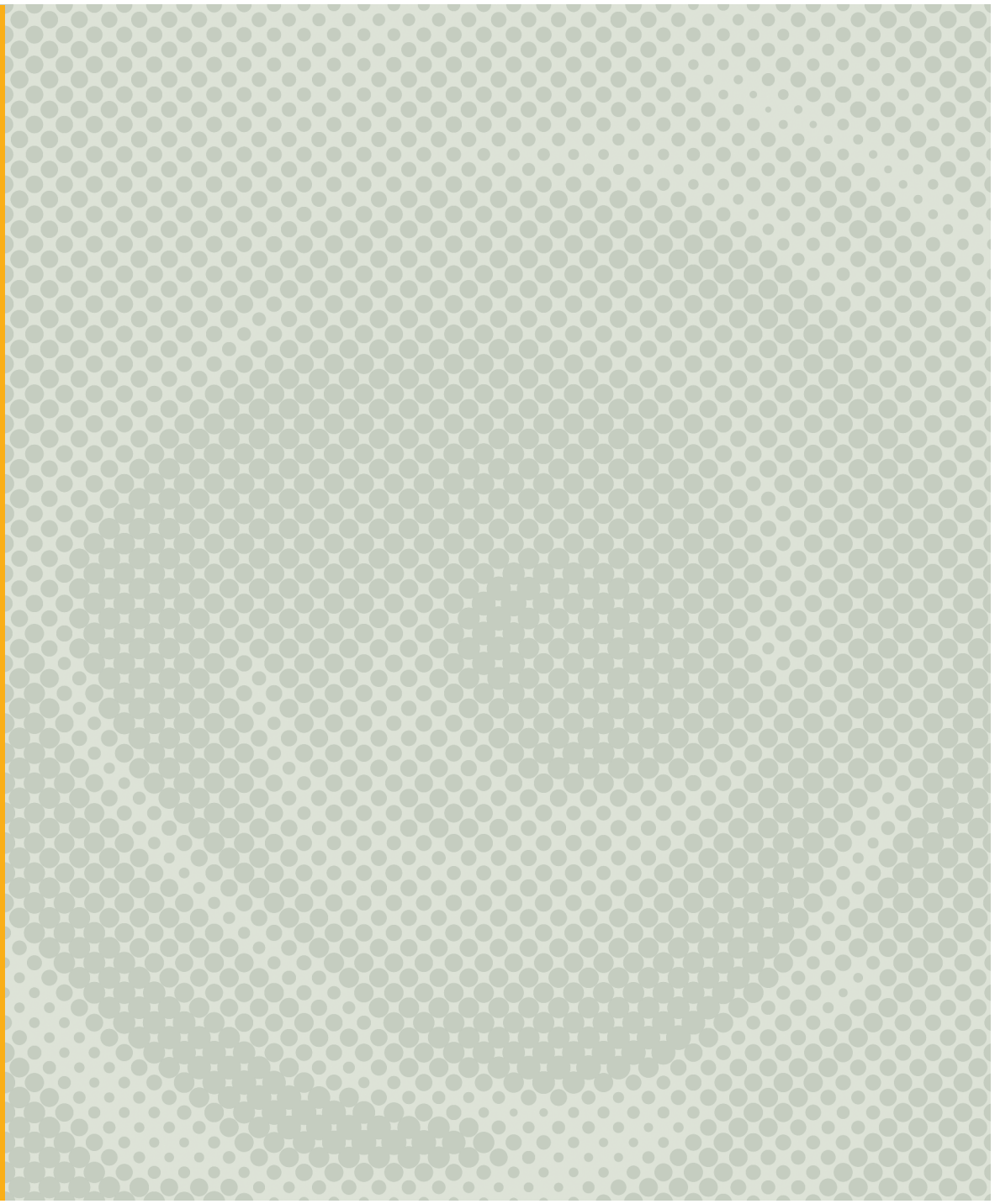
Product quality in solar dried carrots, tomatoes and onions

Produktkvalitet i soltørkede gulrøtter, tomater og løk

Kathrine Strøm

Norwegian University of Life Sciences
Department of Chemistry, Biotechnology and Food Science
Master Thesis 30 credits 2011



ACKNOWLEDGEMENTS

This Master thesis was conducted at the Norwegian University of Life Sciences (UMB) and Sokoine University of Agriculture (SUA) during the spring and summer 2011. My supervisors were associate professor Trude Wicklund (UMB), and Dr. Bernadette K. Ndabikunze (SUA). I want to thank all my colleagues and the staff at UMB and SUA.

-My supervisors Trude Wicklund and Bernadette K. Ndabikunze for their good advice and support during the planning, throughout the experiments and with the completion of this work.

-Laboratory managers both at SUA and UMB with help and advices during the experiments.

-Raymond Jofrey and Richard Mongi for their patience with all our questions regarding drying techniques and technology.

-Siv Berit Lundberg for being such an amazing travelling and working partner through our stay in Tanzania, and after returning to Norway!

-All my Norwegian friends for support and encouraging through my years of study.

-All my Tanzanian and Norwegian-Tanzanian friends for your hospitality, humor, and joy of life. You made my stay to a memory I will keep in my heart for the rest of my life.

-Kyrre, Mom, Dad and my brother for always being there for me!

Ås, August 2011.

Kathrine Strøm

SAMMENDRAG

Formålet med denne oppgaven var å undersøke hvordan to ulike typer soltørker påvirket produktene som ble tørket, og egenskapene som ble undersøkt var vanninnhold, reduksjon i L-askorbinsyre (L-AA), mineral- og proteininnhold, samt mikrobiologisk aktivitet. De to tørkene benyttet i forsøket var en kabinettørke kun varmet opp av direkte solenergi med naturlig luftgjennomstrømning, og en tunelltørke der et solcellepanel koblet til en vifte som drev luft varmet opp av solen, over produktene som skulle tørkes.

Grønnsakene undersøkt var gulrøtter, tomater og løk. I tillegg til de nevnte undersøkelsene ble gulrøttene behandlet med ulike typer forbehandling for å se hvordan dette påvirket rehydrerings evnen og utseende på de tørkede prøvene. Tomatene ble tørket både som skiver og båter for å se om det var mulig å produsere større biter av tomatene, da dette kunne vært et nytt produkt på det lokale markedet.

Resultatene viste at det var en signifikant korrelasjon mellom vanninnhold og type tørke brukt og produktene tørket raskere ved bruk av tunelltørken. Det var høyere mikrobiologisk aktivitet i prøvene fra kabinettørken, og begge de nevnte faktorene kan ha vært et resultat av høyere temperatur og lufthastighet i tunelltørken. Det ble også funnet vekst av koliforme bakterier i noen av prøvene, og det kunne tyde på for dårlig hygiene ved behandling av prøvene. Mugg og/eller gjærvekst ble sett i alle prøvene og dette kan være uheldig, da enkelte muggarter kan danne toksiner under gunstige forhold.

Høyere temperatur var antagelig også grunnen til at høyere degradering av L-AA ble observert i prøvene fra tunell tørken. Mineral og proteininnholdet i prøvene viste ingen klare forskjeller mellom prøvene fra de to tørkene, men proteininnholdet kunne se ut til å være noe høyere i tomatprøvene fra tunelltørken, sammenlignet fra samme prøver tørket i kabinettet. Når en sammenlignet resultatene fra mineral analysen av grønnsakene i dette forsøket med verdier oppgitt i matvaretabeller fra Norge og Tanzania, varierte mineralinnholdet i retning høyere innhold av enkelte mineraler i noen av grønnsakene, mens verdiene var lavere for andre mineraler og grønnsaker. Jordsmonnet grønnsakene ble dyrket i kan ha påvirket dette utfallet.

ABSTRACT

The purpose of this thesis was to investigate how two different types of solar dryers affected the products that were dried, and the properties examined were water content, reduction in L-ascorbic acid (L-AA), mineral- and protein content, and microbiological activity. The two dryers used in the experiment was a cabinet dryer heated by direct solar energy and a tunnel dryer with a solar panel connected to a fan who forced air heated by the sun, over the products to be dried.

The vegetables studied were carrots, tomatoes and onions. Contents of L-AA, minerals and proteins were examined and the microbiological quality of the products was evaluated. In addition to the aforementioned studies were the carrots treated with various degree of pre treatment to see how this affected the rehydration ability and appearance of the dried samples. The tomatoes were dried both as slices and boats to see if it was possible to produce larger pieces of tomatoes, as this could be a new product in the local market.

The results showed that it was a significant correlation between moisture content and type of dryer used, and the products dried faster when using the tunnel dryer. There was a higher microbiological activity in the samples from the cabinet dryer, and both these factors could have been the result of higher temperature and air velocity in the tunnel dryer. It was also found growth of coliform bacteria in some of the samples, which could indicate inadequate hygiene in the treatment of the samples. Mold and/or yeast growth was seen in all samples and this may lead to the presence of toxins produced by certain mold species. This growth was consistent with previous studies of mold growth in dried products.

Higher temperature was probably also the reason for why higher degradation of L-AA was observed in the samples from the tunnel dryer. Mineral and protein content of the samples showed no clear differences between the samples from the two driers, but the protein content could appear to be somewhat higher in tomato samples from the tunnel dryer, compared with the same samples dried in the cabinet. When the results of the mineral analysis of the vegetables in this experiment was compared with the values given in food tables from Norway and Tanzania, some of the samples showed higher levels of certain minerals in some of the vegetables, while values were lower for other minerals and vegetables. The soil conditions where the vegetable was grown may have influenced this outcome.

CONTENTS

1 INTRODUCTION

This work is a part of a collaboration program between The Norwegian University of Life Sciences (UMB) and Sokoine University of Agriculture (SUA), Tanzania. The project title is: "Empowering Women to Participate in the Higher Level of Fruit and Vegetable Chain Through Production of Dried Products". The program includes projects within economics, agriculture and other agricultural sciences, and food technology which this thesis is a part of.

This part of the project focused on solar drying of vegetables. The field work and some of the laboratory work was performed during a two moths stay at SUA, while the remaining analyzes was completed at UMB after the return from Tanzania. The vegetables chosen for this study was carrots, tomatoes and onions.

The main focus of this work was to study the effect of different solar dryers on the final products, with an emphasis on nutritional, microbiological and technological quality. To find the optimal production methods, it was desirable to find a technique that gave rapid drying to a moisture content where microbiological activity was slowed down and the shelf life of the product was increased. The method should in least possible degree deteriorate the nutritional state of the products, and in the same time the sensory attributes of the product, with texture and appearance in focus, should be of good quality. The rehydrating capacity of the products was important, since the dried vegetables mostly are used in boiled soups, sauces and stews. Finding a method that meets all these requirements was of course not realistic. The goal was therefore to find a method where one could make reasonable compromises between the different quality parameters and hence produce a tasty, nutritional and safe product with good consumer acceptability.

This part of the project focused on the food technological part, and how to best treat tomatoes, carrots and onions before, during and after the drying process.

The main targets were to:

- *Try out different ways of pretreatment of the raw carrots before drying.*
- *Study how different size of the tomato samples to be dried, influence the final product.*
- *Investigate the nutritional value of the dried material, compared to the fresh products.*
- *Look at the microbiological activity in the various dried samples and see if the different drying techniques influence the growth of bacteria and fungi.*

1.1 NOMENCLATURE

UMB = The Norwegian University of Life Science

SUA = Sokoine University of Agriculture

a_w = Water activity

MT = Matvaretabellen

TFCT = Tanzania Food Composition Tables

RC = Rehydration Capacity

RR = Rehydration Ratio

CD = Cabinet Dryer

TD= Tunnel Dryer

L-AA = L-Ascorbic Acid

PCA = Plate Count Agar

VRBA = Violet Red Bile Agar

RB = Rose Bengal Agar

MC = Moisture Content

RH = Relative Humidity

AV = Air Velocity

DM = Dry Matter

2 THEORY

2.1 THE PROJECT

This work is a part of the NUFUGe-2008/10181 project. The title of the project is "***Empowering Women to Participate in the Higher Level of Fruit and Vegetables Value Chain Through Production of Dried Products***", and is a part of the "NUFU-Women's rights and gender equality" program. It is a collaboration work between Norwegian University of Life Science (UMB), (Ås, Norway) and Sokoine University of Agriculture (SUA), (Morogoro, Tanzania), and the time line is 2008-2012.

Women are greatly responsible for the agricultural work being done in Tanzania, and thus they are important contributors to the economy for the local society and the whole country.

As the situation is now, lack of knowledge and resources, causes the fact that woman mostly are responsible for primary production of fruits and vegetables, and sale on the local markets. Much of the products produced are lost due to difficult storage and transport facilities, and therefore the economical profit is less than it theoretically could be. With better knowledge and access to the technology that can increase the value of the products, training in how to meet the requirements to ensure food safety and stable quality, and help to organize the transport and sales chain, the economic gain could be increased.

It is therefore necessary to teach the women the skills needed to meet the necessary requirements, and thus provide a better economy to their families and their local society.

The main targets of the project is to: identify a drying technique suitable for the products and conditions, develop a product line consisting of high quality products with good consumer acceptance and commercial potential, work out an effective distribution line for the products, and to describe a conceptual framework which can be used not only in this project, but also in other areas to enhance the economic influence of different groups of the local communities (SIU 2011).

2.2 TANZANIA IN NUMBERS

The United Republic of Tanzania is situated on the east coast of Africa. The population was in 2010, 43.542 million residents. Although Tanzania is a very poor country, they have in recent years experienced a steady economic growth. Unfortunately, this growth has not reach the poor part of the population and data from 2007 shows that 88,5 % of the population lives on less than 1 dollar a day. 37,5 % of the population lives below the national poverty limit and 35 % of the population suffer from malnutrition. The infant mortality is 6,7 %, and 21,8 % of the kids are underweight. The life expectancy for a child born in 2010 is 58 years. In rural areas 45 % of the people have access to clean drinking water, and only 21 % have access to well established, sanitary facilities.

When it comes to education, 80,8 % of the children complete the primary school, which is close to the United Nations *Millennium Development Goals* who says: "*by 2015 children everywhere, boys and girls alike will be able to complete a full course of primary schooling*."

Nearly 80 % of the population is employed in agriculture-related occupations and most of the farming is done on a self-sufficiency level. (UNA 2011)

2.2.1 Food consumption and nutrition in Tanzania

A nation's social and economical development is strongly related to the population's nutritional status. Children's physical performance as proper muscle and bone structure, and cognitive performance as brain development and concentration, is both dependent on right nutrition. A balanced diet also gives better resistance to common infections and diseases. If the children are well nourished, this will later be reflected in a population of more educated, stronger and healthier people. Tanzania Food and Nutrition Centre refers to numbers that says about 50 % - 75 % of pupils go to school without eating breakfast, and they don't get any meals served during the school day. Many school children have a long way to school, and they are often away for 12 hours or more. They only have their evening meal prepared at home, to cover their nutritional needs(*Tanzania Food and Nutrition Centre* 2011). (Mazengo et al. 1997) presents numbers of protein intake that says: 2 % of kids under 12 years, 13 % of people from 35 to 44 years and 35 % of people from 65 to 74 years has a protein intake below

recommendations from FAO/WHO. In the same order, the percent of subjects with a daily energy intake below the recommended was 47 %, 75 % and 55 %.

Tanzania has a tropic climate, with a short and a longer rainy season. Different fruits and vegetables has different growth seasons, and this leads to periods when the population eats a lot of a specific vegetable, for other seasons of the year not eat it at all. This again makes the diet richer in different nutrients during the season. During the peak of a specific fruit or vegetables season, one could see that not all the products are eaten because they simply have too much of it. If the farmers could preserve the excess products in a way that maintain the nutritional value of the products, and gives it a longer shelf life, this could give the population a more balanced diet through the year.

A healthy and nutritional snack to bring, and eat on their way to school could give a better basis for spending a long day with learning for the kids. Dried fruits and nuts could be a good source for some of the vitamins and minerals essential for the body and also carbohydrates, fat and proteins that gives energy.

Buying a cabinet dryer (CD) would be too expensive for most of the small farmers in the villages around Tanzania. Helping the people to buy a sheared dryer, where the different families of the community can come to dry their products could be a useful help for the people, to better preserve their agricultural products.

2.3 SOLAR DRYING OF VEGETABLES

To dry foods by the help of heat from the sun is a technique that people have used for thousands of years. This is a way to preserve the raw material, extend the shelf life, and make a change in the products taste and texture. When it comes to methods for drying, it ranges from simply laying the product on the ground, and let it dry by exposure to the sun, to large industrial processes, with use of electricity or other heat sources under controlled conditions.

The term “sun drying” is used about the simple technique of spreading the products on the ground, exposed to sunlight. When drying the products under some kind of shelter, and with collection of heat in a chamber, it is called “solar drying”.

The easiest way to dry food is by sun drying. The advantage of this technique is that one basically doesn't need any specific equipment, so it is a low cost way of handling the products. The disadvantages are many, and one of the main problems is spoilage of the products due to weather conditions as rain, wind and dust. The hygiene is difficult to maintain, with contamination from the soil. Animals, insects and birds, are also a source for contamination of microorganisms, and they also cause losses by eating the products if they get the chance. The direct sunlight could lead to deterioration of the nutritional value, and also cause color changes. The long drying time needed for drying the products could allow fungi and other microorganisms to grow on the products (Sharma et al. 2009).

To optimize the drying of food products, considering decreased drying time, optimal hygienic conditions, and controlled conditions to best maintain the nutritional value of the products, the industry use mechanical dryers as spray dryers, freeze dryers, drum dryers, electric cabinet dryers and steam dryers. The equipment used in this drying industry, requires large amounts of energy from electricity or fossil fuel. Both the increasing prices and the supply of fossil fuel could be a big challenge in many developing countries, and especially in rural areas. The costs of equipment used for mechanical drying is also often very high.

The solar driers can in regions with stable warm and sunny weather, be a good alternative to mechanical driers. Especially in areas with no access to electricity, or unstable power supply, this could be an important method for preserving food. Compared to primitive sun drying, the advantages are protection from unstable weather conditions, no direct sun exposure and protection from animals, insects and birds. A solar dryer will also dry the products in a shorter time, because of collection of heat from the sun, which gives less time for microorganisms to establish and grow. The fact that the process is environmental friendly, because no fossil fuel is used makes it even a better method in the future (Sharma et al. 2009).

The advantages with a solar dryer compared to sun drying are:

- Drying time is decreased because the hot air is trapped inside the cabinet. The possibility to preheat air before it enters the cabinet, allows better circulation of dry, hot air around the products.
- Efficiency is increased due the decreased drying time, and higher capacity. This leads to less spoilage of the raw material, caused by shorter post harvest storage.

- The hygienic conditions are much better, since the system is closed. The fast drying time decreases microbiological growth, and production of toxic compounds from bacteria and fungi.
- Degradation of nutrients sensitive to light and high temperature is lower, because of shorter time of heat and light exposure, and no direct sunlight. The look and taste of the products will also appear better after a shorter drying time. (Sharma et al. 2009)

In this work, two different solar dryers were studied. The two different dryers used were a simple cabinet dryer (CD) and a tunnel dryer (TD) with a fan driven by electricity from a solar panel.

2.3.1 Solar dryers

Solar dryers are often categorized into direct, indirect and specialized solar dryers. The direct dryer is defined as a closed chamber covered with transparent glass or plastic. Some of the solar radiation is reflected by the cover of the drier, while some of the radiation passes through the cover. Some of the radiation passing through is taken up by the products as heat energy; some are taken up by the other surfaces inside the dryer, while the rest is reflected back as solar radiation. The cover of the dryer closure the reflected energy inside the cabinet, and the temperature inside the drier rises. Moisture from the products is removed by convection. The CD is an example of a direct dryer. (Sharma et al. 2009)

In the indirect drier, the products are sheltered from the direct sun. This protects against cracking of the surface and discoloration of the products. The solar radiation is collected and used for heating up the air in a preheating chamber. The radiation hits a collector inside the preheating chamber, and the air passing the collector is heated by convection. The heated air flows up and into the drying chamber, heating up the products, and moisture will be transported away from the products. The moisture leaves the cabinet through vents in the top of the drier. (Sharma et al. 2009)

A specialized drier are often designed to fit specific products optimal drying conditions, and is often combined with hybrid systems, using additional energy in the drying process. (Sharma et al. 2009)

Hybrid dryers using additional heat energy is the most efficient of the systems described, and the indirect method gives generally faster drying than the direct method.

Dryers could also be divided in active and passive dryers. Circulation in the passive drier is caused by buoyancy from the heated air. In active driers, a fan is creating the air movement, and these systems are called forced convection dryers. (Sharma et al. 2009)

There is a wide range of dryers used for drying crops, with different combinations of drying methods, and energy collectors being used. Different fruits, berries and vegetables, may have specific requirements for the drying process. Below, a description of the type of dryers used in this project is presented.

2.3.2 Cabinet dryer with natural ventilation

This is a direct dryer, with passive air circulation. The dryer consist mainly of two units, an air heating unit and a drying chamber. The frame of the dryer is made by planks of wood, which are easy available most places. Both units is covered with transparent plastic, and the sheet of the units are black. The plastic cover protects the products from rain, dust, birds and direct sun. The air inlet and outlet are covered with mesh to avoid flies and other insects to reach the products. In the air heating unit, the air gets preheated, and natural convection makes the heated air flow from the heating camber and in to the drying camber. The vegetables are spread on trays, placed in the drying chamber. The trays are made as a wooden frame, covered with mesh. The preheated air flows from the lower parts of the drying chamber, between the pieces of vegetables and out in the upper part of the cabinet. The trays are easy to remove from the cabinet, and should be cleaned between every batch. The temperature of the CD used for drying vegetables at SUA was measured by (Mongi 2010) when drying tomatoes in May 2010. The initial temperature at 7.00 am was 21,3 °C, maximum temperature was reached at 13.00 pm and was 53,3 °C and end temperature at 18.00 pm was 37,4°C. Average temperature through the measuring period was 40,66 °C. The initial relative humidity (RH) was at the same time 59 % at 7.00 am, 19 % at 13.00 pm and 32,7 % at 18.00 pm. The average RH was 31,81 %. Figure 1 shows the CD used by SUA for drying vegetables. The plastic used for this dryer was visqueen which is the plastic (Ndawula et al. 2004) described as the best compared to polyethylene or open sun drying, regarding less

vitamin C and β-carotene losses. (Pangavhane & Sawhney 2002) reports that the CD could at least halve the drying time of grapes compared to traditional sun drying. This would probably to certain extend, be the same for other vegetarian products as well.

Figure 1: Front side and backside of the cabinet dryer used by SUA.

2.3.3 Tunnel dryer with solar panel

This is a direct dryer with active air circulation. The dryer consist of two parts, one for preheating of the air, and the second for drying the products. A solar panel runs a fan that sucks the fresh air into the preheating part, and forces the heated air to pass over and around the products to be dried. The dryer is raised from the ground with a base of bricks. The frame is in steel, and the whole tunnel is covered with transparent visqueen. The sheet of the preheating area is black, and the sheet of the drying part is white. The products to be dried are placed on a white synthetic mesh, which allows air to flow around the products. This is taken out and cleaned between every batch of product. The plastic covering the products, and the mesh in the ends of the drier, protects against animals and insects, dust and rain, when the dryer is closed. Some dust may follow the air stream through the dryer, but most is kept outside. A temperature and RH profile of the TD used at SUA is not yet performed, but (Hossain & Bala 2007) presented a maximum temperature range from 40 °C to 66 °C at the solar collector outlet, for a TD similar to the one at SUA. Figure 2 shows pictures of the TD at the SUA drying field. The solar panel is placed on top of the dryer in the left backside corner.

Figure 2: The tunnel dryer used by SUA, to the left filled with onions, tomatoes and carrots, and to the right without products.

The drying process of both the CD and the TD are batch productions with a relative slow drying rate compared with mechanical dryers, but faster than sun drying. The dryers are suitable for solid products with moderate initial moisture content, as fruits and vegetables, and intermediate size of the pieces to be dried (Fellows 2000). Final MC in both CD and TDs are described as moderate, which means that they are not as effective as for example a fluidized bed dryer.

2.3.4 Changes in the products during the drying process

(Fellows 2000) defines rehydration as "*the application of heat under controlled conditions to remove the majority of water normally present in a food by evaporation*".

When a product is dehydrated, many of the reactions usually taking place in the fresh material slows down, because of the reduced water activity in the product. Water plays an essential role in the chemical and physical processes within foods. One of the desired consequences of decreasing the MC of a product is that the microorganisms that are present in the product can no longer grow. Many of the organisms found in the fresh material require a specific MC to grow. When the sample is dehydrated, these will no longer grow, but they can still survive. Still it is important to remember that lowering the moisture content, gives an opportunity for

microorganisms with a lower moisture requirement to grow. To stop all kind of microbiological growth, the MC in vegetables needs to be around 5 % (Damodaran et al. 2008). Dehydration also decreases enzyme activity within the product.

When drying a product, there are three important inter-related factors that influence the capacity of air to remove water, and this is: the amount of moisture already present in the air, the temperature of the air and the amount of air passing around the food (Fellows 2000). The air velocity (AV) is an additional factor and affects the speed of moisture transported away from the surface of the product. When the water evaporates from the products, a boundary layer of air containing water vapor will be firmed around the product. As faster this boundary layer is carried away by moving air, the faster more moisture is allowed to evaporate from the product. This means that for getting good drying condition, dry air with high temperature, low RH and high AV are required.

The drying process goes through two stages. The first step begins with the surface of the product getting heated by the hot air. Then the drying begins, and water is moved from the interior of the product with the same speed as the moisture evaporates from the surface. This is called the "constant-rate period". Under this stage, the surface still remain wet, until "critical moisture content" is reached. The temperature of the product stays close to the wet-bulb temperature of the drying air under this period. When the products MC falls below the critical MC, the drying rate slowly decrease and reach the equilibrium moisture content. This is known as "the falling-rate period", and the rate of water movement from the interior to the surface of the product, is lower than the rate at which water evaporates to the surrounding air. Now the surface dries out, and the temperature rises close to the dry-bulb temperature. This can lead to heat damage of the product, if the temperature not is controlled. When the product in the drier is placed on a tray of mesh, most of the heat transfer is by convection, but there may be some heat transfer by radiation as well. The falling-rate period is the longest of a drying process, and factors that controls the drying range changes from those important in the constant-rate period, to mass transfer of water within the product being the important one. What controls the mass transfer is: *liquid movement by capillary forces, diffusion of liquids,* caused by concentration differences of solutes in the product, and *water vapor diffusion* in spaces filled with air inside the product, caused by vapor pressure gradients (Fellows 2000).

When drying a product, the surface area of the product is very important. A long, thin slice of a product will dry faster than a squared piece of the same weight, due to the much larger

surface exposed to the surrounding air, where water can evaporate. If the piece of product is too thick, the water in the interior of the product can use long time to reach the surface and evaporate. In this case, spoilage of the product caused by microbiological or enzymatic reactions may occur. It is therefore important to slice the product in a size suitable for the drying process used in the specific case. Blanching the product before drying to stop enzymatic activity, must be considered for the specific product to be dried (Fellows 2000).

Other important factors to think of when drying foods, are the composition and structure of the product tissue. The orientation of fibers in the vegetables allows more rapid movement of moisture along the fibers, than across them. Cell rapture by blanching may also increase the drying rate, when the cell membranes are punctured, and water are more easily available for moisture movement. High content of solutes as sugars, starches or salts increase the viscosity inside the products, and slow down the evaporation of the water, but the water is in those cases bound, so the water activity will be lower (Fellows 2000).

The amount of product placed in the drying chamber will also affect the drying rate, since more moisture will be present in the air inside the chamber. Another important factor regarding even product quality is to have the same size of all the products being dried. If the difference is too big, one will find small pieces that are too dry and larger pieces which is not dry enough.

Basically a higher air temperature will get a faster drying rate, but higher temperature will give more unwanted effects as degradation of vitamins, and changes in color and taste. Too high temperature could also dry out the surface to quick, and moisture are getting trapped inside the product, so the last stage of the drying process will be more slowly.

When all the different factors regarding the food material is known, it is possible to calculate the optimal drying temperature, AV and drying time. When it comes to solar dryers, it is a challenge to control those factors. The temperature is dependent of the heat from the sun, and if it is a cloudy day, the heat could be lower but maybe the RH higher. This will affect the drying time of the products and give a longer drying time, as (Togrul & Pehlivan 2002) described, when they compiled a mathematical model to describe the solar drying curve of apricots. The AV of the CD is driven by natural convection from the heated air, so it is difficult to control this. In the TD, a fan is blowing the hot air through the drying chamber, and in this case it could be possible to adjust the rate of the fan, if it is adjustable. (Fellows 2000)

2.3.5 Changes in the food

When drying food, all products will undergo a change that reduces the quality of the product, compared to the fresh raw material. The most noticeable change for the consumers, are the texture, and loss of color, taste and aroma. The less visible, but yet important change, is loss of nutrients.

2.3.6 Texture

Pretreatment as peeling, cutting and blanching, all cause major changes to the product, and factors that influence the texture change could be gelatinization of starch, or crystallization of cellulose. This leads to internal stress to the cells, and the cell walls gets cracks, and get compressed. The surface of the dried product gets shriveled, and matt. When the products are rehydrated, the water absorption is slow, and the rehydrated material will not obtain the same firm and crisp texture as the fresh raw material. The degree of textural changes to the dried and the rehydrated material varies between different products, their DM and solutes present. Some get a tough and sticky consistency, and others get hard and crispy. The degree of drying also affects the textural appearance. High temperature and fast drying generally gives a greater change in texture compared to lower temperature and moderate drying time (Fellows 2000).

2.3.7 Taste and aroma

The taste and aroma of the dried and rehydrated products are often less than in the fresh products. Volatile components that are soluble in water could evaporate together with the moisture from the products. Higher temperature leads to higher degree of volatiles loss. Another source for aroma loss is oxygen. When the water is removed from the vegetable tissue, a porous structure allows oxygen to permeate the cells and an oxidation of volatiles and lipids could occur. Most vegetables are low in lipids, but especially in carrots, oxidation of carotenes could lead to an unwanted odor. To reduce these changes, right storage conditions are important. Vacuum or controlled atmosphere packaging and low storage

temperature are both important. Protecting the products from light and moisture will also give less storage degradation of the dried products. Another option is to add antioxidants to the products (Fellows 2000) .

2.3.8 Color

The color of the dried products often comes out matt and pale compared to the fresh material, due to the dry surface reflects the light in another way. In vegetables, carotenoid and chlorophyll pigments goes through chemical changes caused by heat and oxidation. Residual polyphenoloxidase enzymes could lead to browning during storage. Blanching the products before drying could prevent this (Fellows 2000).

2.3.9 Nutrients

When it comes to degradation of the different nutrients in the dried vegetables, it is a large difference between the values presented in the literature as (Fellows 2000) argue, and (Gornicki & Kaleta 2007) shows by studying the MC (which can affect vitamin degradation) of the same products with different pretreatment and (Bechoff et al. 2009) by testing vitamin degradation in the same product dried in three different dryers. The reason for this could be the great variation in size and shape of the pieces, different pretreatment, temperature, time, exposure to light and oxygen. Generally the loss from preparation and pretreatment exceeds those from the actual drying stage of the process. Ascorbic acid is water soluble, and when the water evaporates from the products, it could react with other solutes at higher rate. It is also sensitive for heat and oxidation, so low drying temperature and fast drying is important to prevent too much degradation. Low oxygen and MC during storage are also factors that prevent further degradation during storage. The fat soluble vitamins are mostly contained within the dry material of the product. Heavy metal catalyst occurring in the water of the products gets more reactive when the MC decreases and oxidation accelerates. The peroxides from oxidation react with the fat-soluble vitamins, and the vitamins are degraded. Low oxygen levels, low temperature and protection against light, reduces the loss during storage.

The proteins of the vegetables are not affected substantially, regarding biological value (Fellows 2000).

2.4 REHYDRATION

When rehydrating a dried product, it will never regain the same condition as before drying. The drying process causes changes in the permeability of the cell walls, loss of osmotic pressure and solute migration. Crystallization of polysaccharides and coagulation of proteins also contribute to irreversible changes of the plant tissue. The less elastic cell walls and the reduced water holding capacity of protein and starch, all decrease the rehydration ratio (RR) of the products. If the drying process is optimal, the negative factors regarding rehydration of the cells will be less than with a poor drying technique (Fellows 2000). Table 1 shows approximate RRs for some selected vegetables, presented in (Fellows 2000). Fellows do not describe the drying or rehydration method for the products, and the RR could probably change with different techniques.

Tabell 1: Rehydration ratio for dried carrots, onions and tomatoes.

Product	Rehydration ratio
Carrots, sliced	7,0
Onions, sliced	5,5
Tomato flakes	5,0

(Fellows 2000)

2.5 THE VEGETABLES

Tomatoes, carrots and onions are all important sources for many of the essential nutrients required by the human body, and they are all ranked high on the scale of which vegetables that contributes most to the total nutrient intake (Wills et al. 2007). Carrots, tomatoes and onions are all grown locally in the Morogoro area. In the growth season for the different vegetables, one will find big quantities of the mentioned vegetables at local markets, and not

everything is consumed. The lack of chilling possibilities makes storage more than a few days difficult, and post harvest losses are big.

Carrots, tomatoes and onions are all used on a regularly basis in the Tanzanian cooking. Preservation of the excess vegetables by drying could be a good way to conserve the products for sale, or to use in periods with less access to these vegetables.

2.5.1 CARROTS (*Daucus carota* L subsp. *sativus*)

The carrot is a biennial plant, which gives a taproot the first year. This root is the part of the plant that is eaten.

The plant originals from the Middle East and Central Asia, and has been cultivated for more than two thousand years. The carrot was brought to Spain by the Arabs one thousand years ago and from then it has spread all over Europe and further to Africa (Grønt 2011).

Carrots are now grown in many parts of the world, thanks to its ability to grow under different temperature conditions. The optimum air temperature for growing carrots is between 16 and 25 °C. Heavy and frequent rainfall could lead to a reduction in the root color, and too dry conditions may cause cracking of the roots. In tropical areas, the altitude must be 500 m above sea level or higher, to get economic yield from the production. If the daylight is to short, it could give reduced content of β-carotene in the roots.

A carrot of good quality should show a deep yellow to orange color, have a pleasant flavor and be crisp. The recommended storage temperature is below 4 °C. Temperatures above 10 °C gives good growth for plant pathogen bacteria and fungi, which leads to higher post harvest losses. Considering the lack of chilled storage conditions in most of Tanzania, the roots will lose their quality rapidly, and the crispness will disappear, do to transpiration. To store the carrots for later use, drying is therefore a good method. The combination of willingness to grow, pleasant taste, and high content of β-carotene makes it a popular vegetable in Tanzania, as well as in the rest of the world (Tindall 1983).

In Tanzania, they use carrots in many different soups and stews, as well as eating it raw mixed with other vegetables as a salad. Dried carrots is well suited for mixing in the boiled dishes,

since these often are boiled for a long time, which allows the dried pieces to be properly rehydrated.

Carrots come in a variety of colors, and the dominant color seen in markets in Tanzania is the orange one. What gives the carrot its color is β-carotene who is a carotenoid who can be converted to retinol by the human body. Retinol is an active vitamin A compound. It is required to maintain the structure of the eye, and prolonged deficiency of vitamin A can lead to blindness (Wills et al. 2007).

Osmotic dehydration is a method of pretreatment used on fruits and vegetables to decrease the drying time, and protect the cell tissue of the products from damages caused by the heat and dehydration. The method is based on the nature's desire for achieving equilibrium of solutes. When a piece of vegetable is dipped in a sugar solution, the solute sugar is in a higher concentration outside the cell walls of the product than inside. Basically, water will flow out of the plant cells, and solutes will get transferred into the cells to achieve the desired equilibrium inside and outside the cells. Solutes often used for osmotic dehydration are salts and sugars, and the concentration of the solutes in the solution affects the degree of dehydration in the product being soaked in the solution (Torreggiani 1993).

According to (Aktas et al. 2007) pretreatment of vegetables such as addition of sugars could avoid damage to the tissue structure. In their study, sucrose and threalose was studied, with focus of the positive effects of threalose. The samples was first blanched, and then dipped in sugar solutions with different concentrations, and different exposure time. The results showed that this procedure gave products with less shrinkage, compared to products produced without any pretreatment. They suggest that trehalose was better for this purpose than sucrose, but treatment with sucrose also showed positive effects, as less shrinkage and lower initial water content compared with non-treated samples. The samples without sugar treatment showed higher drying rates at the end of the drying period.

Shrinkage and uneven drying of the products is normally seen when drying carrots without pretreatment (Aktas et al. 2007). This makes rehydration slower because of the uneven structure, which could make it more difficult for the water to reach the surfaces inside the folds. The appearance of the products could also be better with less shrinkage. A pretreatment method that reduces the shrinkage could be a good way to increase the quality of the dried carrots. (Gornicki & Kaleta 2007) performed a experiment which showed that blanching carrot cubes in water for 6 minutes gave a higher drying rate than blanching it for 3 minutes.

They also blanched samples in a 5 % brine solution for 3 minutes, and those samples had an even lower drying rate than the carrots blanched for 3 minutes in water. They did not describe any analyses of the vitamin degradation in relation to the temperature treatment, and as described earlier higher temperature is associated with higher vitamin degradation. According to those result, it seems that longer blanching time gives faster dehydration, while shorter blanching time gives less vitamin degradation. Which one of these properties that is most important must be evaluated when deciding blanching time for the production.

2.5.2 Rehydration of carrots

The ability of dried carrots to rehydrate is important for the consumer. Dried carrots are quite hard and if not completely rehydrated during the cooking time of the meal, it will come out as tough lumps in the soup or stew.

2.5.3 TOMATOES (Lycopercicon lycopersicum (L.))

Tomatoes originate from South America, and were brought to Europe around 1500. It was probably brought to Africa by Portuguese traders. It is now grown all over the world, where the climate allows it.

The plant is a variable herb, which grows up to 2 m in height. The fruits are a fleshy berry with a thin peel, covering a relatively thin layer of firm flesh, who surrounds a jelly like mass, containing many flat seeds. The ripe tomato is found in the colors yellow, orange and red, with a wide variety of size and shape (Tindall 1983).

There are many cultivars of tomatoes, suited different temperature and soil conditions. Low RH combined with high temperatures can affect the fruit setting, and both high and low temperature can reduce the color of the tomatoes. In tropical areas, tomatoes are successfully grown at altitudes up to 2000 m, but yields are often highest at around 1000 m. The modern cultivars are quite day length neutral, but high intensity of light is favorable for higher amounts of ascorbic acid. The plant is sensitive to heavy rainfall, and too high RH could lead

to leaf diseases. The yield is generally higher during dry periods with proper irrigation (Tindall 1983).

The fruits could be harvested when still green, and ripened under warm, dry conditions. If the tomatoes are to be stored, it is important to decrease the temperature in the fruits to 13-15 °C rapidly after harvesting. Fruits harvested when red, could be stored at 13-18 °C and a RH between 85-90 % in 8 days to mature. If the tomatoes are kept at 25 °C or higher, the production of the red pigment lycopen will be reduced, and the fruit will not reach the desired red color. High storage temperature for the ripe tomatoes limits the storage time till just a few days.

The ripe tomato should have a rich orange to red color, with a round shape and firm flesh without soft spots. In Tanzania, the tomatoes are often used in cooked meals, but they are also served raw together with other vegetables. Dried tomatoes is ground to a flour and used in sauces and stews. The tomato is rich in vitamin A, C and minerals. It also contains lycopen, who acts as an antioxidant (Tindall 1983).

2.5.4 Shape of the dried tomatoes

Dried tomatoes are used in Tanzania, and the local people often grind the slices to tomato flour, and use it in soups and sauces. (Gallali et al. 2000) presents results from sensory analyses in Libya, that indicate that dried tomato boats were preferred among consumers, compared to sliced tomatoes. They point out the high moisture loss caused by the thin slices, to be the negative parameter of the preparation technique. The attributes focused on in the study was texture, color and flavor. Their results also showed that tomatoes dried with natural sun drying were better accepted, than tomatoes dried in a solar drier.

Thin slices are easier to dry, because of a larger surface exposed to the air, compared to the volume of the product. This is the method used earlier by the people working for SUA.

2.5.5 ONIONS (*Allium cepa* L. var *cepa*)

Onions are a biennial herb, and are normally grown for its bulb. It originates from Central Asia, and was early brought to Egypt and India. Now onions are grown all over the world.

The onion requires quite high temperatures for the bulbs to form, but the tropical areas do most places have the right temperature, even at high altitudes, and altitude around 1000 m above sea level, normally gives the highest yields. The optimum temperature during the vegetative growth is between 18-25 °C. The short days in the tropics could lead to poor bulb formation, although some cultivars are better suited to these conditions. The short day light often leads to a flavor milder than what we are used to from the onion grown in Europe. The tolerance for heavy rainfall is quite good, and moist soil is required during the growth period, especially during the bulb formation. When the bulb is firmed and the leaves have withered, it needs a long dry period to mature as desired (Tindall 1983).

Onions of good quality should have a dry outer skin, without any damages that expose the fleshy meat inside. The onion should be firm, without soft or dark spots. If the onions are to be stored, they need a ripening or curing time of 14-20 days. Onions could be stored over 25 °C, but it is then important to keep a RH between 75-85 %, to prevent water loss (Tindall 1983).

Onions are one of the vegetables that have been preserved by sun drying for a long time. In Tanzania, onions are often used in soups and stews, but also raw, together with other vegetables.

2.5.6 Nutritional value of the vegetables used in this study

The values listed in Table 2 is from Norwegian “Matvaretabellen”(MT) (Mattilsynet et al. 2006) and Tanzanian “Tanzania Food Composition Tables” (TFCT) (Lukmanji et al. 2008). The values presented from MT are those for “carrots, imported, raw”, “Tomato unspecified, raw” and “Onion, Norwegian, raw. This was the categories best suited to match the products. The values from TFCT are general for carrot, tomato and onion, grown in Tanzania. As discussed earlier, the amount of nutrients varies a lot and is affected by numerous factors. The

numbers presented in the table must therefore be considered as an indication of which values the vegetables may contain (Nes et al. 2004). To better be able to compare the values in these tables with the results from this study, the amount of the different nutrients in the DM has been calculated.

Table 2: Presentation of the nutritional composition in carrots, onions and tomatoes, as described by the Norwegian "Matvaretabellen" and the "Tanzanian Food Composition Tables". The table presents both the values present in the raw product, and calculations of the content in the dry matter of the product.

	Matvaretabellen						**Tanzania Food Composition Tables**					
	Carrot		**Onion**		**Tomato**		**Carrot**		**Onion**		**Tomato**	
	g per 100 g fresh	g per 100 g DM	g per 100 g fresh	g per 100 g DM	g per 100 g fresh	g per 100 g DM	g per 100 g fresh	g per 100 g DM	g per 100 g fresh	g per 100 g DM	g per 100 g fresh	g per 100 g DM
Edible part %	89	**100**	93	**100**	100	**100**	99	**100**	93	**100**	100	**100**
Water g	90	**0**	88	**0**	94	**0**	90	**0**	88	**0**	94	**0**
DM	10	**100**	12	**100**	6	**100**	10	**100**	12	**100**	6	**100**
Protein g	0,9	**9**	1,1	**9,2**	0,9	**15**	0,9	**9**	1,3	**10,8**	0,9	**15**
Fat g	0,2	**2**	0,1	**0,8**	0,2	**3,3**	0,2	**2**	0,2	**1,7**	0,3	**5**
Carbo-hydrate	6,8	**68**	7,7	**0,8**	2,4	**40**	9,6	**96**	9,2	**76,7**	4,6	**76,7**
Fiber g	2,4	**24**	2	**16,7**	1,2	**20**	2,8	**28**	1,3	**10,8**	1,1	**18,3**
Retinol µg	0	**0**	0	**0**	0	**0**	841	**8410**	0	**0**	87	**1450**
β- carotene µg	3 950	**39 500**	0	**0**	737	**12 283**	0	**0**	0	**0**	0	**0**
L-ascorbic acid mg	2	**20**	6	**50**	17	**283,3**	5,9	**59**	7,4	**61,7**	19	**316,7**
Ca mg	41	**410**	21	**175**	13	**216,7**	33	**330**	23	**191,7**	5	**83,3**
Fe mg	0,3	**3**	0,4	**3,3**	0,3	**5**	0,3	**3**	0,2	**1,7**	0,5	**8,3**
Na mg	12	**120**	2	**16,7**	5	**83,3**	69	**690**	4	**33,3**	9	**150**
K mg	282	**2 820**	201	**1 675**	337	**5 616**	320	**3 200**	146	**1 216**	222	**3 700**
P mg	35	**350**	38	**316,7**	24	**400**	35	**350**	29	**241,7**	24	**400**
Mg mg	10	**100**	11	**91,7**	13	**216,7**	12	**120**	10	**83,33**	11	**183,3**
Zn mg	0,2	**2**	0,2	**1,7**	0,2	**3,3**	0,2	**2**	0,2	**1,67**	0,1	**1,67**
Cu mg	0,04	**0,4**	0,1	**0,4**	0,1	**1**	0	**0**	0	**0**	0,1	**1,67**
Mn mg	0	**0**	0	**0**	0	**0**	0,1	**1**	0,1	**0,83**	**0,1**	**1,67**

2.6 MOISTURE CONTENT

The MC in fresh vegetables are generally high, and as reported in (Mattilsynet et al. 2006), carrots has a initial MC of 90 %, tomatoes 94 % and onions 88 %. To extend the shelf life of these products, a large amount of this water needs to be removed. When considering how low the MC needs to be, to prevent microbiological activity, it is usually the water activity that is discussed. The water activity (a_w) of a food is the water content that is available for chemical, enzymatic or microbiological activity. This is also known as the "Relative Vapor Pressure" (RVP), and the definition is "*the ratio of vapor pressure of water at the same temperature*"(Fellows 2000). The a_w of a food depends on: the amount of water present in the product, the temperature and the concentrations of solutes in the water (mainly sugars and salts), and is described by a number between 1 and 0, where water = 1. (Fellows 2000) suggest the a_w of dried fruits with a MC of 15-20 % to be 0,6 and the a_w of dried vegetables with a MC of 5 % to be 0,2. Halophilic bacteria (lives in salt conditions) or osmophilic bacteria (lives in dry conditions) grows to a a_w minimum of 0,75, and xerophilic (lives in dry conditions) yeast and molds could grow down to a a_w of 0,6. The absolute a_w for heat resistance of bacterial spores are 0,25 (Fellows 2000).

(Sharma et al. 2009) presents a table of MC defined as safe, concerning when deterioration of the products stops. Table 3 shows the values for the relevant vegetables.

Table 3: The initial moisture content, final moisture content and maximal allowable temperature for carrots, tomatoes and onions, as described by (Sharma et al. 2009).

Crop	Initial moisture content (% w.b)	Final moisture content (% w.b.)	Max. allowable temperature (°C)
Carrots	**70**	**5**	**75**
Tomatoes	**96**	**10**	**60**
Onions	**80**	**4**	**55**

(Sharma et al. 2009)

The MC presented in the table is quite low, so to get a picture of what MC normally seen in the different dried products, earlier research material has been studied.

(Lin et al. 1998) dried carrots to a final MC of 10 %. (Gallali et al. 2000) presented a MC of 5,5 % for tomato slices, 10,45 % for tomato boats, and 13,10 for onion slices, all dried in a solar dryer of mixed type.

2.7 VITAMINS

Fruits and vegetables are good sources for many of the vitamins we need to maintain a healthy organism. The appearance and concentration of the vitamins in the different products varies between different cultivars and varieties, maturity stage, climatic conditions, and growth conditions as soil quality and available nutrients/fertilizers.

After harvest, all fruits and vegetables will undergo a loss of vitamins. The plant tissue is metabolically active post harvest, and this allows enzymatic activities, that can lead to changes in the vitamin content. Both the vitamin activity and the distribution of the chemical forms can be influenced over time. Factors as physical damage, storing conditions and time from harvest to processing, all influence the vitamin activity in the raw materials ready to be processed. This means that it is important to reduce stress of the plants during harvesting and transport, reduce the temperature under storage and transport as low as recommended for the specific product, and process it as fast as possible to get an end product as nutritional as possible. (Damodaran et al. 2008)

2.7.1 Loss of vitamins during processing

During processing, many factors can affect the nutritional value of the products and may cause vitamin degradation. What affects the different vitamins vary, but generally high temperature, and the time exposed to the high temperature are important. Also oxygen and light are important factors when it comes to vitamin degradation. Stability of the different vitamins interesting for this experiment will be discussed later.

When peeling the products, vitamins in the peel will naturally lead to loss of nutrients situated in the peel. If the product are rinsed, transported in water, or blanched after peeling, a leaking

of water soluble vitamins can occur. Factors as pH, temperature and size of the surface exposed to the water, can all affect the grade of vitamin loss.

During the processing of dried carrots, the raw material first was peeled, and then sliced before blanching the products. During blanching, disruptive enzymes are inactivated, and microorganisms are reduced. Inactivation of enzymes can also give a better stability to some of the vitamins during the following storage of the products. This is an important stage to maintain the overall quality of the products. There are different methods for blanching the products, and hot water, hot air, flowing steam and microwave treatment are some of them. Blanching in hot water, cause severe leaching of vitamin to the water. When using the hot water method, high temperature, short time-treatment is preferred, as this method improves the retention of heat labile vitamins (Damodaran et al. 2008).

L-ascorbic acid and Vitamin A was of special interest in the work with the dried vegetables.

2.7.2 L-ASCORBIC ACID

L-Ascorbic acid (L-AA), or more commonly used Vitamin C, is a water soluble vitamin that is found in many fruits and vegetables. L-isoascorbic acid and D-ascorbic acid acts in a chemical manner, similar to L-AA, but have no vitamin C activity, and no nutritional value (Damodaran et al. 2008).

2.7.3 Biological function of L-ascorbic acid

L-Ascorbic acid takes part in many of the body's complex system. All the different reactions where it plays a role are not yet known, but many are. L-AA is an efficient intracellular reducing agent, because of its ability to get oxidized. It is therefore one of the important antioxidants, and protects other components as polyunsaturated fatty acids and vitamin A and E. Regulation of the red-ox potential in the cells are probably the most important biological function of L-AA. In the lack of L-AA it is specially the connective tissue that is affected. The vitamin is necessary in formation of the intracellular substances of the connective tissue,

cartilage tissue, bone tissue and dentin. Further L-AA is involved in conversion of cholesterol to bile salts, and formation of several neurotransmitters as serotonin and noradrenalin.

L-AA also probably acts as an anticarcinogen for some kind of cancers. And is promotes absorption of iron from the diet.

Deficiency could be seen as scurvy. Early signs are fatigue and shortness of breath, followed by muscle and bone pains and hemorrhages under the skin. Bleedings from the gums and tooth's will loosen. If the patient is given a high dose of L-AA, it will recover quite quickly. Recommended daily intake is 75 mg (Nes et al. 2004).

2.7.4 Stability of L-ascorbic acid

Since L-AA is a water soluble vitamin, it is highly exposed to loss through leaching when cut in pieces or if the vegetable surface has wounds. Heat treatment and freezing, who also damage the plant tissue, allows further leakage of L-AA. L-AA is a strong antioxidant component, and is highly exposed to oxidation, especially in the presence of transition metal ions such as Cu^{2+} and Fe^{3+}. Factors as light and heat accelerate the process, while pH, water activity and oxygen concentration strongly influence the rate of reaction (Damodaran et al. 2008).

2.7.5 VITAMIN A

Vitamin A is a fat-soluble vitamin and refers to a group of unsaturated hydrocarbons, which are nutritionally active. They include some of the carotenoids, retinol and related compounds. Preformed vitamin A does not occur in vegetables, so their vitamin A activity comes from certain carotenoids. According to new recommendations, the relationship between retinol and β-carotene is 1:12. This means that 12 μg β-carotene is believed to yield 1 μg retinol activity equivalent. (Damodaran et al. 2008)

2.7.6 Biological function of vitamin A

Vitamin A is essential for normal bone formation and growth, and it is necessary for normal cell differentiating in cells such as epithelial cells and adipocytes. It is also important in formation of mucus in the mucous membranes, and without vitamin A, the mucous will not maintain their anti inflectional mission. Vitamin A is active in different reactions regarding reproduction in both males and females. What people often associate with vitamin A is the night vision. To be able to see in weak light, the light sensitive pigment rhodopsin is necessary. Rhodopsin is put together of vitamin A in the form of retinol and a protein called opsin. When light hits the rhodopsin, a cleavage between vitamin A and opsin occurs, and the vitamin is lost. To form new rhodopsin, more vitamin A is necessary.

An early sign of vitamin A deficiency is reduced night vision, and also reduced color vision. The mucus of the eye will after longer deficiency dry out, and lead to permanent reduction of the vision. If the patient is given vitamin A, the condition can be partly healed, but without vitamin A the illness xerophthalmia could develop. If not treated, this decease will lead to keratomalacia with damage of the cornea, and permanent blindness.

Vitamin A deficiency is most often seen in kids younger than 5 years, living in developing countries. The condition is often seen together with protein-energy deficiency. Deficiency during pregnancy could lead to malformation of the fetal (Nes et al. 2004).

The human body normally absorbs retinoids effectively, but malabsorption of fat could decrease the amount which the body can absorb. Recommended daily intake is 900 mg for males and 700 mg for females.

2.7.7 Stability of Vitamin A

Both retinoids and carotenoids contains conjugated double bond systems, and the trans isomers gives the strongest vitamin A activity, this is also the most dominating form of retinoids and carotenoids occurring naturally in foods. During heat treatment, the trans isomers can be converted to cis isomers, and this causes a loss of vitamin A activity.

Degradation of vitamin A occurs in a parallel way as oxidative degradation of unsaturated lipids. Oxidation occurs with exposure to oxygen, and higher temperatures generally increase the oxidation rates. When drying a product, the water activity decrease, and this generally cause a decreased oxidation rate, probably because the mobility of reactants decreases. On the other hand, continued removal of water, could in some foods result in accelerated oxidation at low water activity. Degradation of vitamin A can also occur by indirect effects of free radicals. Other factors that can cause isomerization is light exposure, acid, chlorinated solvents and dilute iodine(Damodaran et al. 2008).

β-carotene shows the greatest provitamin A activity among the carotenoids, and carrots are rich in this specific carotenoid. Typical β-carotene content in raw carrots vary between different sources, but the Norwegian "Matvaretabellen" suggest 3 950 µg/ 100 g imported raw carrot, and the "Tanzania Food Composition Tables" says 10 092 µg/ 100 g. The Norwegian values for the Norwegian carrots are 5 250µg/100g, so the low value for impotent carrots may assume some loss during transport and storage.

(Damodaran et al. 2008) describes difference in β-carotene loss in cooked, dehydrated carrots, dried in three different driers. The results showed a decrease from 980-1860 µg/g solids in fresh carrot to 870-1125 with a vacuum freeze-drying method, and 636-987 µg/g solids with a conventional air-drying method.

(Bechoff et al. 2009) investigated vitamin A retention in sweet potatoes, using three different driers. Their results showed that solar drying and drying with hot air gave no significant difference in retention, but it was a significant difference between hot air drying and sun drying. The loss of total carotenoid was respectively 13 % with hot air, 21 % with solar drying and 33 % with sun drying. (Ndawula et al. 2004) looked at β-carotene and vitamin C retention in mango fruits and cowpea leaves, dried under open sun and in two different solar dryers, one covered with visqueen and the other with polyethylene. The results showed that both the solar dryers had a higher retention of both vitamin C and β-carotene. They also found that blanching the cowpea leaves before drying gave an even better retention of the two nutrients. The loss in leaves without blanching was 63,16 %, while the blanched samples lost 53,37 %. The blanching gave slightly lower vitamin C content, but the difference was not significant.

When looking at these studies, it seems that solar dryers give a better retention of the discussed vitamins, compared to sun drying. The positive effect seen after blanching is also interesting, when having the planned pretreatment of the carrots in mind.

2.8 MINERALS

Minerals are inorganic substances that play an important role in many of the complex systems of the body. Minerals are found in vegetable or animal foods, and the sources of the minerals are the ocean or the soil where the animal or plant is found. The amount of minerals found in the plant, vary with the soil it has grown, and the amount in the soil again are dependent of the rocks it is made of. This is the reason why the amount of minerals in plants from the same cultivar grown in different soil could vary quite much.

The amount of minerals in the body is about 4 % of the body weight. The daily needs of minerals vary from only milligrams of some of the minerals to a gram of others. (Nes et al. 2004)

The daily recommendations of the different minerals are taken from The Norwegian Directorate for Health publication "Norwegian recommendations for nutrition and physical activity" (Norwegian recommendations for nutrition and physical activity 2005) The amount varies between age and gender, so the number presented are those for male and female from 18-30 years. Table 4 presents the minerals tested in this work.

Table 4: Presentation of the minerals to be tested in this study, where biological function, deficiency symptoms, sources for the minerals and daily recommended intake are included.

Mineral	Biological function	Deficiency	Good sources	Recommended daily intake	References
Calcium (Ca)	Bone and tooth mineralization, muscle contraction, blood clotting, hormone secretion and nerve transmission	Increased risk for osteoporosis, hypertension and some cancers	Milk, yoghurt, cheese, fortified juices, tofu, kale and broccoli	800 mg	(Damodaran et al. 2008)
Phosphorus (P)	Bone mineralization: DNA and RNA synthesis, phospholipid synthesis, energy metabolism and cell signaling	Deficiency is rare, but low consumption could impair bone mineralization	Almost all foods, but high protein foods and cereal products are especially rich	600 mg	(Damodaran et al. 2008)
Copper (Cu)	Included in a number of metalloenzymes, most of them	Rare, but can be seen in malnourished kids	Most foods, but higher	0,9 mg	(Nes et al. 2004)

	oxidases. Together with zinc and manganese, it is included in superoxide dismutase (SOD), which is an enzyme protecting against cell damage caused of oxygen radicals. Copper is also related to hemoglobin syntheses and utilization of iron, formation of connective tissue and cholesterol and glucose turnover	after repeated infections and chronic diarrhea and in early born infants feed exclusively on cows' milk	amounts are found in liver, shellfish, nuts, raisins and dried legumes		
Iron (Fe)	Oxygen transport with hemoglobin and myoglobin in the blood system. It is also included in respiration and energy metabolism, destruction of hydrogen peroxide and DNA synthesis	Deficiency is widespread and effects include fatigue, anemia, impaired work capacity, impaired cognitive function and impaired immune response	Meat, cereal products, fortified foods and green leafy vegetables	9 mg for males and 15 mg for females in menstrual age	(Damodaran et al. 2008)
Zinc (Zn)	Cofactor in metalloenzymes and in the regulation of gene expression	Growth retardation, impaired wound healing, delayed sexual maturation and impaired immune response	Red meat, shellfish, wheat germ and fortified foods	9 mg for males, and 7 mg for females	(Damodaran et al. 2008)
Manganese (Mn)	Included in several enzyme systems	Not known	Vegetarian foods	2-5 mg	(Nes et al. 2004)
Magnesium (Mg)	Cofactor for many enzymes	Deficiency is rare	Green leafy vegetables, milk and whole grains	350 mg for males, and 280 mg for females	(Damodaran et al. 2008)
Potassium (K)	Is together with iron one of the two most important cations in the human body. Most of the potassium in the body (98 %) is found in the cytosol of the cells	Often seen together with the protein deficiency illness kwashiorkor or conditions with chronic diarrhea. Potassium deficiency	Most foods contain potassium, but fruits and vegetables are good sources	1,5 – 3,0 g	(Nes et al. 2004)

		caused by low intake through the diet is rare			
Sodium (Na)	Predominant cation in extracellular fluid, it controls extracellular fluids volume and blood pressure and is required for transports of many nutrients into or out from the cells	Rare except from in people performing endurance sports	Mainly from salt used in prepared meals	Daily need for NaCl is 0,5-1 g	(Damodaran et al. 2008)

Mineral analyzes

When a sample of food is incinerated, inorganic substances does not burn. Analyzing the ash of the product will tell which minerals that is present in the food.

2.9 PROTEINS

Proteins are essential for all living organisms. They are essential for formation of new cells, and maintenance of existing cells. When considering proteins necessary for a healthy growth in animals and human, it is not only the amount of proteins, but also the quality of the proteins that is important (Nes et al. 2004). Proteins from animally sources are of high quality due to their content of essential amino acids. Some plants as cereals and legumes are vegetables with relatively high amounts of proteins, and are an important source of proteins in many parts of the world. The vegetables studied in this work, carrots, tomatoes and onions are not particularly high in proteins, but small amounts are present.

2.10 MICROBIOLOGY

One of the most important issues in food safety is microorganisms. Presence of microorganisms can both spoil the product, and cause serious illness in the individual eating

it. Not all bacteria are pathogenic, and one will find harmless microorganisms almost everywhere. Many of the pathogen strains also need to be represented in a high amount before they causes any harm, while others cause illness with the presence of only few organisms. Yeast and molds are also microorganisms causing problems in food production, and can be responsible for spoilage of the plant tissue. Some molds could also produce dangerous toxins in the product, causing life threatening intoxications in humans and animals. *Aspergillus flavus* and *A. parasiticus* are both common species in tropical areas, and are responsible for production of Aflatoxins (Zinedine et al. 2006). Aflatoxins are acutely toxic if present in high amounts, but are also carcinogenic. The Norwegian Veterinary Institute presents maximum tolerated levels for aflatoxins meant for human consume as 4µg of all the different aflatoxins per kg foodstuff. African people are often exposed to fungal and mycotoxin contamination through their staple food (Hell et al. 2009). There is almost non control of the products. Contamination through vegetable products could promote even higher intake of toxic components. Decreasing the growth conditions in dried vegetables is therefore very important.

As a food manufacturer, it is a great responsibility to prevent that the consumers gets ill from the food being produced, and control of the production process is essential. Microorganisms can grow over a wide range of temperature. Some psychrophilic strains can grow at temperatures down to – 5 °C, and in the other end of the scale we find thermophile organisms that grow at 90 °C. In the temperature range between 10-50 °C one find the mesophiles (Tortora et al. 2007). Many microorganisms will survive at temperatures both higher and lower than those mentioned, and can start grow again when temperature is back at the bacteria's optimum. Bacteria strains as certain *Bacillus* and *Clostridium* species can produce spores that are extremely resistant to external influence as freezing, heat, drying and chemicals. Under the right conditions the spores can germinate, and the bacteria will start to grow again (Adams & Moss 2000).

All vegetables have a natural microbiological activity on the surface and some of these organisms can cause spoilage of the plant tissue through storage. Degradation of the mature plant material is a natural part of the nutrient turnover, where nutrients are recycled for building up new plant material the next growth season. Anyway, these bacteria are not so important concerning food safety in the dried products. As long as the raw material are good, without any signs of tissue degradations, the products can be dried and give a good product.

What can cause dangerous bacterial growth is contamination from external factors as contaminated water for irrigation, natural fertilizers, feces from birds and animals, and insects bringing microorganisms from one surface to one other. To investigate if there are bacteria from feces present in foods, detection of coliform bacteria are often used.

Coliforms are defined as "*those organisms capable of fermenting lactose in the presence of bile at 37 °C* " (Adams & Moss 2000). This includes most strains of *Escherichia Coli*, but also bacteria that are not predominantly from feces, such as *Citrobacter* and *Enterobacter*. A more restricted group of coliforms are the fecal coliforms, which grows at higher temperatures (in example 44-44,5 °C). The *E. coli* strain O157:H7 8 (VTEC) which is associated with serious illness after food born contamination, do not grow well at 44 °C. Therefore coli test are often performed at temperatures of 37 °C to detect if the sample are contaminated with feces(Adams & Moss 2000). Many strains of *E. coli* are not harmful at all, but if they are present in the sample, it indicates that fecal contamination has taken place, and there is a possibility that pathogens are present in the products.

In the temperature conditions in tropical areas, it is mostly the mesophile bacteria with minimum growth temperature from 5-15 °C, optimum at 30-40 °C and maximum at 40-47 °C which is found (Adams & Moss 2000).

Molds and yeasts are often present in dried fruits and vegetables. (Hell et al. 2009) investigated the presence of mycoflora and mycotoxin contamination in a selection of dried vegetables, tomatoes included. In tomatoes with a MC of 10,2 %, they detected growth of *Aspergillus niger*, *Aspergillus flavus* and *Fusarium verticillioides*, but no aflatoxins was found. Storage conditions could influence some of the molds, but many are not affected. (Misra 1981) found that *A. flavus* among others grew at both 20 and 30 °C and with RH between 60 and 80 % in dried spices. He also found that polyethylene bags were better for slow down fungi growth during storage compared to cotton and gunny bags.

To prevent food borne deceases, it is important to use clean water when rinsing the products, washing the processing equipment, and cleaning the hands. This is important under the whole production process, from the vegetables is cleaned before the process, and to the final products is being packaged. It is also important to make sure the products not are in touch with animals, birds, flies and other unclean surfaces.

When products are being dried, it is important that the drying process goes as quick as possible. When the sun heats up the products in the drier, the temperature of the wet product will not heat up to the same temperature, because of the evaporative cooling. The temperature in the driers may kill some of the bacteria, but many will survive, and could even get more heat resistant during the process. In the night, the temperature decreases, and if the product is not dry enough after the day, bacteria now get good growth conditions. During nighttime, the air also gets more humid, and the products will absorb some of the moisture from the surroundings (Adams & Moss 2000).

3 MATERIALS AND METHODS

3.1 THE PRODUCTION LOCATION

The production of the dried vegetable analyzed in these experiments was performed close to the Tanzanian city Morogoro. The city is situated south of equator (6° 49′0″ S, 37° 40′0″ E), and the altitude is about 500 m above sea level. The temperature lies between 20 °C in the night to 30 °C during daytime, with small variations through the year. The year is divided in four seasons, with a small and longer rainy season, and a small and longer dry season. In this project, the drying where performed from the end of January when the weather is dry, to the middle of March, which is the beginning of the smaller rainy season.

The production area was located at a flat field surrounded by forest and agricultural areas. The space around the dryers was open, to allow good circulation of the air.

Preparation of the vegetables took place inside a building, fitted for production purpose. The production tables made of stainless steel was easy to move, so cleaning of the areas was easy to maintain. The building did also contain a room for storing clothes, packaging material and so on. Another room was for storing the trays used in the dryers.

On production days, the floor was cleaned with water and soap, and all the surfaces to be in contact with the food were sterilized with water added chlorine. The cutting boards, knives,

drying trays and other equipment were also sterilized with chlorine. The drying cabinets were cleaned with water and soap before every batch was put in the dryer.

To get good drying conditions, with hot dry air as fast as possible in the initial steps of the drying, all the products where put in the dryer before 10.30 a.m.

To decide when the products were finished, a subjective, visual and sensory evaluation was performed by the trained personal working with the dryers and the students performing the experiment.

Temperature and humidity measurements were not performed in this experiment, but it could have been interesting to know how the climate inside the different dryers changes during the drying time.

Figure 3: The picture to the left shows the building and drying area where the drying experiments were performed. To the right, one can see the interior of the production building, where peeling, cutting and preparation of the samples took place.

3.2 PREPARATION OF DRIED SAMPLES

3.2.1 DRYING OF CARROTS

As (Aktas et al. 2007) suggested, threalose was the preferred sugar for pretreatment.

In this study, the purpose was to use methods possible to perform in rural areas at the location of the local driers in the villages. The methods performed in this study, should be possible to repeat out in the field. Sucrose is easy available almost everywhere, and that is not the case with threalose. Therefore sucrose treatment was chosen for this particular experiment.

As described in (Fellows 2000) pretreatment of the products are generally responsible for more of the nutrient loss than the actual drying process. Blanching is an important step in pretreatment of a variety of vegetables before further processing. This is a mild heat treatment but (Damodaran et al. 2008) describes that the inactivation of enzymes gives a beneficial effect of stabilizing many vitamins throughout the further storage of the products. Further (Damodaran et al. 2008) writes that rapid heating and cooling is the best method to prevent unnecessary losses. Steam balancing and cooling in ice water could be the preferred method, but this requires more sophisticated equipment than available at the production location in this particular study. When blanching the carrots in this specific experiment, hot water was used, as this was the most relevant method for use in rural villages.

Materials:

Carrots, grown locally and bought at the local market the same morning as the samples were prepared. The color was strong orange, and the roots were of medium length and thickness.

Methods:

In lack of clean water, the tap water to be used in the sugar treatment was boiled using a gas heater and a kettle outside the production building. The water was chilled down and prepared with sucrose bought in a local store. One concentration was made with 10 % sugar and one with 20 % sugar.

The carrots where washed, pealed and the ends were removed, before the carrots were sliced in slices of about 2 mm thickness, by using a locally bought slicing equipment called “Super

Slicer". The samples were blanched in boiling water for two minutes to inactivate peroxidase, before they were cooled down by putting them in pure water or sugar solution. The samples were treated as described in Table 5.

Table 5: Sugar concentration and exposure time for the carrot slices.

Sugar content	Minutes
0 %	10
10 %	10
10 %	20
20 %	10
20 %	20

After the sugar treatment, samples was spread on the trays, and left in the driers for 52 hours in the CD, and 52 hours in the TD. They were then collected, packed in plastic bags, and put in a freezer at – 18 °C. The reason for why the samples were frozen was that Ugandan commercial producers of dried fruits and vegetables did this after drying to prevent growth of microorganisms. There was no documentation of why they followed that procedure.

To study what would happen with samples during the drying process if they got contaminated with coliform bacteria before the drying, carrot samples was contaminated with water added animal feces. The staff working with dried fruits and vegetables at SUA, meant that carrots was less problematic to dry compared to tomatoes. Not to get any disturbance by products not getting sufficiently dry, carrots was therefore chosen for this experiment. The sample without sugar treatment was used in the experiment since this was the variant dried earlier in this project.

Preparation of contaminated samples for microbiological experiments:

Dry feces from domestic animals (cow and goat) was collected and dissolved in tap water. Blanched samples prepared as described for the other experiments, without sugar treatment was spread on a tray, and the contaminated water was poured over carrots. This was performed outside the production building, to prevent contamination of the area. The CD was used in this experiment, and it was carried out once.

3.2.2 DRYING OF TOMATOES

When drying tomatoes, earlier in this project, the product has been cut in thin slices before drying. According to (Gallali et al. 2000)s work, which indicated higher consumer preferences for tomato boats, this way of preparation, was performed together with the slices. The difference between the two products was studied too see if this could be an alternative way to process the tomatoes also in the Morogoro area. Cutting a tomato in four was also quicker, than cutting it in thin slices. A smaller surface to weight ratio of the boats was exposed to external degrading factors, compared to the slices. If the results from the drying experiment show that it was possible to produce boats of good quality, it could be a possibility to prepare the boats in oil, as often seen in European dishes. Cooking oil, spices and garlic is easy available in Tanzania, so this could be a way of refining the products and increase the value of the product. Presenting the products for a focus group could be an interesting way to study the consumer reactions of the products

The nutritional state after drying the two different tomato shapes was also to be analyzed to see which method that preserved most of the vitamins.

Materials:

The tomatoes dried in this experiment were grown locally, was of medium size, and the color was orange to red. They were bought on the local market the same morning the drying was to be performed. The tomatoes was cleaned in tap water, and rinsed in tap water containing chloride, before they where dried with a towel.

Methods:

Tomatoes in the cabinet dryer

Some of the tomatoes were cut in four to make boats, and the rest was sliced in slices of about 3 mm thickness. A knife was used for cutting and slicing. The boats and slices was placed on the trays, and put in the drying cabinet. The slices were dried for 52 hours, while the boats were dried for 76 hours. The samples was collected, and half of the samples was kept in a closed plastic bag at room temperature, the other half was put in a freezer with a temperature at – 18 °C.

Tomatoes in the tunnel dryer

After the experiment in the CD, the tomato boats did not get completely dry. Therefore the samples for the TD was cut in eight, to try getting a better result, with samples completely dry. Tomato slices was prepared in the same way as for the CD. The samples were dried for 52 hours. The weather was humid, and with some heavy rain. When collected, most of the samples were black. Many of the tomato slices was also full of mold. Samples without visible mold was paced in plastic bags and frozen.

3.2.3 DRYING OF ONIONS

Materials:

The onions used for drying in this experiment, where all locally grown cultivars, smaller than the cepa grown in Norway, and the color was pale purple. The products for the experiment were bought at the local market the same morning as the experiment took place.

Methods:

Onions where washed in tap water, peeled, and then sliced with "Super slicer" in slices with a thickness of about 2 mm. The slices was laid on the trays, and put into the drier. After 52 hours of drying, the samples were put in closed plastic bags, and one half kept at room temperature, while the other half was put in a freezer at – 18 °C. The same procedure was used for both the CD and the TD.

3.3 MOISTURE CONTENT

About 5 g of the dried sample was put in a small ceramic bowl, and put in a heating cabinet at 104 °C for 16 hours. The weight loss was measured and the MC of the dried vegetable calculated. In this study, there was no time to measure the water activity of the products, but that would have been a more correct way of expressing the water available for the microorganisms.

3.4 L-ASCORBIC ACID ANALYSIS

3.4.1 L-ascorbic acid detection by spectrophotometry

In Tanzania, a spectrophotometric analysis of the vitamin C content was performed. The procedure was as follows:

Reagents: Citrate buffer was prepared by first making a stock solution (0,1 M, pH 4) by mixing 19,21g Citric acid (0,1 M) per 1000 ml dH_2O and 29,41g Sodium citrate (0,1 M) per 1000 ml dH_2O. The buffer was prepared by mixing 330 ml Citric acid stock solution, 170ml Sodium citrate stock solution and 500 ml dH_2O.

DCPIP dye solution was prepared by first making a stock solution of 450 mg 2,6 Dichlorphenolindophenol per 100 ml dH_2O. The working solution was made by diluting the stock solution 1:18 with dH_2O.

Standard curve: Ascorbic Acid (AA) working solution was mixed by first making the stock solution where 20 mg Ascorbic acid was mixed with 100 ml 0, 1 M citrate buffer. The working solution was prepared of 1.0 ml stock solution per 99 ml citrate buffer

The AA working solution was diluted to 0, 1µg, 0, 25 µg, 0, 5 µg, 1, 0 µg and 2, 0 µg by adding citrate buffer.

The standard curve was prepared as follows: a blank reading was done by mixing 0, 5 ml of citrate buffer and 1 ml DCPIP working solution. To the remaining tubes, 3 ml buffer and 1 ml DCPIP working solution was added, and the absorbance at 520 nm was determined.

Procedure of Ascorbic acid determination of dried vegetable samples:

5g of dried sample was rehydrated in a beaker containing 20 ml citrate buffer. After 1 hour, the sample was morted, and 45 ml citrate buffer was added, all together 65 ml citrate buffer. The mashed fruit was filtered through a Whatman #54 filter paper. The filtrate was diluted with 50 ml buffer, which gives a 1.25 dilution. To determine the ascorbic acid content, 3 ml citrate buffer, 2 ml vegetable extract and 1 ml DCPIP was mixed and the absorbance at 520 nm was recorded. This was repeated with all the samples in two parallels.

During this work, making a good standard curve turned out being hard to manage. Without the standard curve, it was not possible to determine the amount of ascorbic acid in the samples (Dashman et al. 1996).

The vitamin C analyses were repeated in Norway, with the use of HPLC-analyses. The procedure was as described in (Wold 2004).

3.4.2 L-ascorbic acid detection by HPLC determination

For preparation of samples for HPLC analyzes:

Procedure:

5 g carrot, 5 g onion and 4 g tomato was added to respectively 70 g, 140 g and 56 g of 1.0 % oxalic acid. The sample was homogenized with a hand processor (Braun MR 400 HC plus 300 Watts) for 1 minute. The homogenized materiel was filtered through a (Whatman 113 V folded filter paper from Whatman International Ltd., Brentord, UK) filter paper, into a beaker. The filtrate was filtered for a second time with a activated (5 ml methanol + 5 ml water) Sep-Pak C18, Waters Corp. from Milford, MA, USA. The three first ml of the filtrate was discarded. The sample was filtered for the third time, using a 0.45 µm VWR Syringe polypropylene filter from VWR International, LLC, into the HPLC test tube.

Injection volume was 5 µl, the flow was $1ml^{-1}$, of 0,05 M KH_2PO_4 at 25 °C, and detection was performed at 254nm. The analyze vas performed on a Agilent system comprising HP1100 liquid chromatography, auto sampler and UV detector from Agilent Technologies, Waldbronn, Germany, consisting of a quaternary pump, an inline degasser, an autosampler, a column oven and a UV detector. The HPLC separation was performed with a Zorbax SB-C18(250 x 4,6 mm, 5 µm) column with a complementary Zorbax XDB C18 (4 x 4 mm, 5 µm) guard column from Agilent Technologies, Waldbronn, Germany.

3.5 MINERAL ANALYSIS

The mineral content of the dried products was analyzed by Atomic Absorption Spectroscopy. The method is based on *the absorption of UV-visible radiation by free atoms of the gaseous state*. The food samples are normally ashed, dissolved in an aqueous solution and heated up inside an instrument that vaporize and atomize the minerals. By letting radiation passing through the sample, the adsorption at different wavelengths corresponding to the specific mineral can be measured(McClements 2011).

Procedure: About 1g dried sample of the vegetable was weighted and dried in a muffle furnace (Carbolite laboratory chamber furnace (CWF)) at 500 °C for 5 hours. The ash was weighted. 20 ml 1, 0 N HCl was added to the sample and the remaining pieces of material was crushed with a glass rod. The samples were left in the acid for 24 hours. After the acid treatment, the samples were filtrated through a Whatman #54 filter paper into a 100 ml volumetric bottle, and distilled water was added till it reached 100 ml. The samples were analyzed by the laboratory staff at SUA.

3.6 PROTEIN ANALYSIS

10 g sample was weighted out, and sent to the laboratory for analyzing, using the Kjeldahl method. Two parallels vas performed. The samples were analyzed by the laboratory staff at SUA.

3.6.1 Protein determination with the Kjeldahl method

The Kjeldahl method is a reference method for determination of organic nitrogen in a sample. It is based on the assumption that dietary fat and carbohydrates not contains any nitrogen. The method also includes the non-protein nitrogen, such as nitrogen from amino acids and nitrate. To get an estimate of the protein content in the samples, a converting factor based on the average nitrogen content in the specific proteins is used. Earlier determinations estimated the average nitrogen content of proteins to be 16 %. This gives the converting factor of N * (1/0.16) or N * 6,25. (Warriss 2000)

The sample being tested is first digested in concentrated sulfuric acid and heated, with the presence of a catalyst usually containing copper sulphate. The amine nitrogen is converted to ammonium sulphate. The samples are then distilled by addition of NaOH (35 %), the pH rise and the ammonium ions is converted to ammonium gas. The gas is condensed into a beaker containing saturated boric acid, and ammonium borate is formed. The last step is to titrate the ammonium borate with 0,2 M HCl, and presence of a color indicator (bromocresol green and methyl red) (Askerud & Kristoffersen 2007).

3.7 REHYDRATION CAPACITY

The products ability to rehydrate properly under cooking, are important for the consumers and is called the rehydration capacity (RC). Dried carrots are usually boiled together with other ingredients and salt in stews, soups and sauces. To simulate the conditions from the preparation method, physiological water with a NaCl content of 0,9 % was used for rehydration.

To study the rehydration rate (RR) of the carrot samples produced with different pretreatment and in different dryers, methods from (Rastogi 2004) was used for rehydrating at 25 °C, and (Lin et al. 1998) for rehydrating at 100 °C. The RR was performed as suggested in (Singh et al. 2010).

The samples of carrots was dried in two different driers, and pretreated with sugar solutions of different sugar content and at different exposure time. There was also left samples without sugar treatment as a control sample. To study the RR over time, two experiments was performed, one with rehydration at 25 °C and one at 100 °C.

Procedure:

3.7.1 Rehydration ratio at 25 °C

10 different samples were tested in two parallels, in total 20 samples.

Approximately 5 g of the dried carrot samples was weighed and placed in a 500 ml beaker. 150 ml physiological water was added, and the beaker was placed in a water bath at 25 °C. After 30 minutes the samples was taken out, and excess water was removed by using absorbent paper. The samples was then weighed and put back in the beaker. This procedure was repeated every 30 minutes in 5 hours.

3.7.2 Rehydration ratio at 100 °C

7 different samples were tested in two parallels, in total 14 samples.

The sample preparation for the experiment was the same as described for 25 °C. The samples were placed in a water bath holding 100 °C. The samples were weighted after 30 seconds, 1, 2, 4, 6, 8, 10, 20 and 30 minutes.

To calculate the RR, the following formula was used:

$$RR = \frac{\text{Weight of rehydrated carrots (g)}}{\text{Weight of dehydrated carrots (g)}}$$

3.8 MICROBIOLOGICAL ANALYSIS

In the microbiological analyzes of the dried products in this study, both the total growth of bacteria, presence of coliforms and fungi, and the difference between the vegetables and production method was investigated.

Microbiological analyses pas performed twice in Morogoro. The results from the first experiment were very inconsistent, so a new experiment was prepared. Problems with sterilizing the equipment for the second experiments were detected, and that was probably the reason for the inconsistent results from the first experiment. Microbiological was therefore performed in Norway after the return.

Introduction to the experiment:

To study the microbiological quality of the products, and look at the survival of the microorganisms in the dry samples, a microbiological experiment was performed at UMB after returning from Tanzania. The total number of microorganisms, coliform microorganisms, and mold and yeast, was the categories chosen for this experiment. For these analyses, Plate Count Agar (PCA) (Casein-peptone glucose yeast extract, from Merck KGaA, Germany), Violet Red Bile Agar (VRBA) (OXOID LTD) and Rose Bengal (RB) (OXOID LTD) added Chloramphenicol selective supplement, were used.

PCA is a non selective growth media, who gives an indication of the total amount of bacteria in a sample. VRBA is a growth medium containing bile salts and crystal violet, who makes it selective for coliform organisms. Coliforms shows as violet/red colonies with the size of 0,5 mm or greater after 24 hours. RB is a selective media, used to enumeration of fungi. It contains rose bengal and a selective antibiotic, and the pH should be adjusted to 7. This combination allows mold and yeast to grow, and bacteria are inhibited. Countable dishes are those between 15 and 150 units. Pepton water (OXOID) was used for dissolving the samples and Ringers (Merck KGaA) was used for dilution of the samples. The agars, dissolving and diluting media was prepared as described by the producer.

Before the main experiments were implemented, a pre experiment was performed, to decide which method was the best for dissolving the bacteria from the products in the dilution media. Three different methods were tested. The first method tested was adding sample to a stomacher bag, adding dilution media, and stomaching for 4 minutes. The second one was to mash the sample in a mortar with dilution media, and the third one was adding the sample to at test tube containing dilution media and mixing it in a turning board for 30 minutes.

The trial in the stomacher was unsuccessful because the dried samples have sharp edges that cut holes in the stomaching bag. The trial with the mortar showed challenges regarding sterilization of the equipment between the different samples being prepared.

The trial experiment showed that the method of adding the sample to a test tube, was the easiest and best suitable one with the dried samples.

Procedure:

After the trial experiment, samples of dried carrots, onions and tomatoes were tested with the preferred method. 1 g of dry sample was put in a test tube with 9 ml peptone water. This gives a 1^{-1} dilution. The test tubes were placed on a wending table for 30 minutes, before the samples was diluted to 1^{-2} and 1^{-3}, and spread in the dishes. The PCA was incubated at 30 °C for three days, VRBA at 37 °C for 24 hours, and RB at 22 °C for five days.

For PCA, all the colonies were counted, for VRBA was only the colonies growing as described for coli counted. For RB was all the colonies counted, and it was registered if it was mold, yeast or both, growing on the agar. The numbers of bacteria found in the samples is presented as the logarithm of the total number of bacteria or mould/yeast per g sample.

3.9 DATA ANALYSES

The correlation between different factors was calculated with the use of "Minitab 15" from Minitab Ltd. (Brandon Court, Unit E1-E2, Progress Way, Coventry CV3 2TE, UK)

A correlation is presented as a number between -1 and 1. The absolute value indicates how strong the linear correlation between x and y are. Values closer to the extreme values indicates strong correlation, while a number close to 0 indicates low linear correlation between x and y. A positive number indicates that the values from the data, lies close to an increasing line, and a negative number indicate that the data lies close to a decreasing straight line. The p-value says if the correlation is significant. Significant correlation has a p-value below 0.05 (Løvås 2004).

4 RESULTS

4.1 ABOUT THE RESULTS

The results regarding the nutrients are calculated to show the amount in the DM of the products. In this way, it was possible to compare the results from this experiment with the values given from the Norwegian "Matvaretabellen" (MT) and the Tanzanian "Tanzania Food Composition Tables" (TFCT).

4.2 MOISTURE CONTENT

The moisture content (MC) in 16 samples dried in the CD and the TD, presented in Figure 4, showed a clear correlation at -0,953 between the drier and moisture content. The difference was significant with a p-value of 0,000. All the samples dried in the TD showed lower MC than the same product dried in the CD. The samples of tomato boats differed clearly from all the other samples with a MC of 34,44 % in the CD and 20,27 in the TD. Rest of the samples from the CD had a MC that varied between 12,03 % and 14,86 %. The MC of the samples from the TD varied between 5,95 % and 13,19 %.

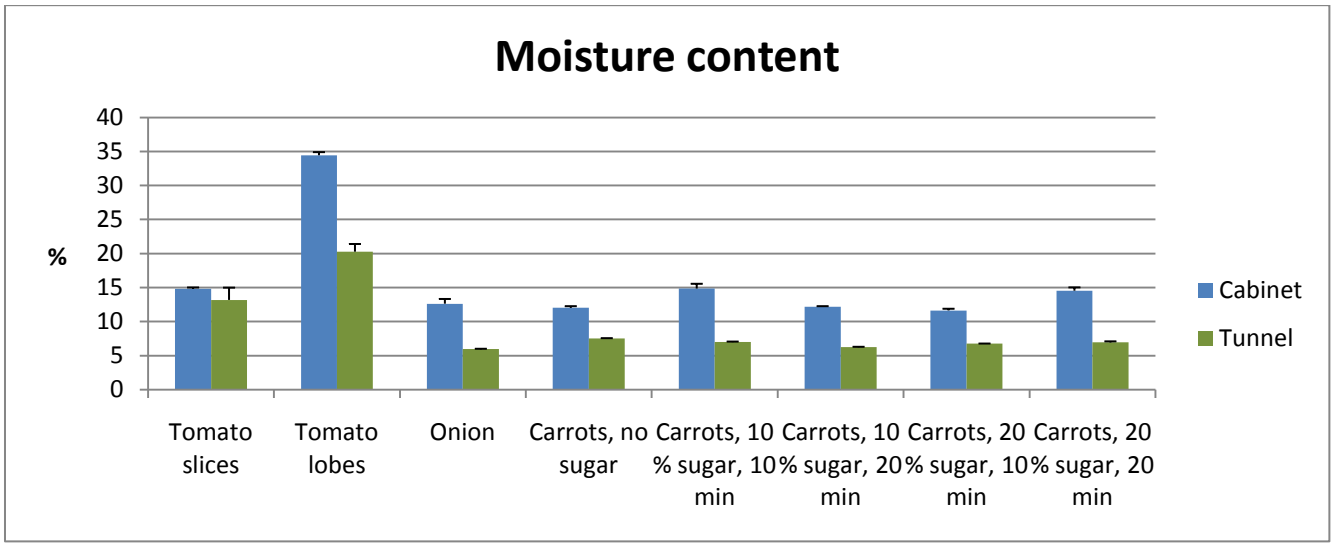


Figure 4: Moisture content in 16 samples of tomatoes, onions and carrots dried in two different dryers. The standard deviation is presented on top of the bars.

4.3 L-ASCORBIC ACID WITH HPLC

The L-ascorbic acid (L-AA) concentration of the dried samples is presented in Figure 5. No L-AA was detected in the dried carrots. Samples dried in the CD had higher content than the same products dried in the TD, and this where the same for both onions and tomatoes

Statistical analyses showed a correlation of -0,351, between the driers and the L-AA content, and the p-value was 0,440 so not significant, when the samples from all of the products were analyzed. Since there was no L-AA present in any of the carrot samples, a correlation matrix with just the carrot and onion samples was performed. The correlation was then higher (-0,644), and the p-value lover (0,241), but still not significant.

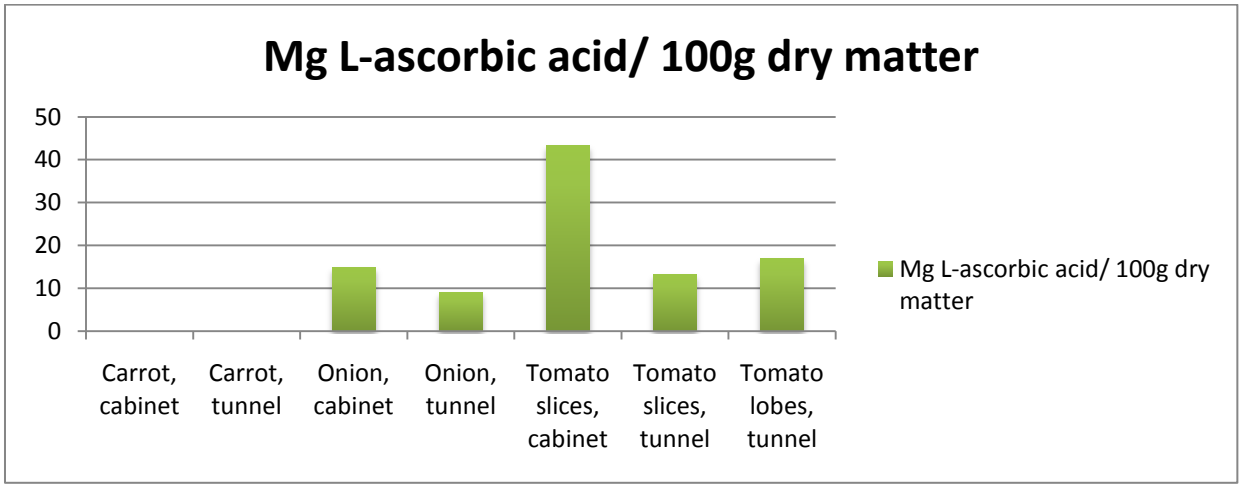


Figure 5: L-ascorbic acid content in dried carrots, onions and tomatoes.

4.4 MINERALS

Table 6 shows the abbreviations of the samples presented in the mineral and protein analyses.

Table 6: Full name and abbreviations of the samples analyzed for minerals and proteins.

Sample	Abbreviations
Carrots Matvaretabellen	Carrot, MT
Carrots Tanzania Food Composition Tables	Carrot, TFCT
Carrots, no sugar, cabinet, frozen	Carrot, CD, 0, F
Carrots, 10 % sugar, 10 min, cabinet, frozen	Carrot, CD, 10/10, F
Carrots, 10 % sugar, 20 min, cabinet, frozen	Carrot, CD, 10/20, F
Carrots, 20 % sugar, 10 min, cabinet, frozen	Carrot, CD, 20/10, F
Carrots, 20 % sugar, 20 min, cabinet, frozen	Carrot, CD, 20/20, F
Tomatoes Matvaretabellen	Tomato, MT
Tomatoes Tanzania Food Composition Tables	Tomato, TFCT
Tomato slices, cabinet, frozen	Tomato S, CD, F
Tomatoe slices, tunnel, frozen	Tomato S, TD, F
Tomato boats, cabinet, frozen	Tomato B, CD, F
Tomato boats, tunnel, frozen	Tomato B, TD, F
Onions Matvaretabellen	Onion, MT
Onions Tanzania Food Composition Tables	Onion, TFCT
Onion, cabinet, frozen	Onion, CD, F

The mineral content of the dried vegetables is shown in Figure 6-15. The blue bars shows the values from Matvaretabellen (MT) (Mattilsynet et al. 2006) and Tanzania Food Composition Tables (TFCT) (Lukmanji et al. 2008). The green bars shows the results from the mineral analyses from this specific study, performed under the work done in Morogoro. The standard deviation between the two parallels was for many of the samples quite high, as one can see from Table 7. Some of the samples had very high standard deviations, caused by incomplete burning during the preparation of the samples.

Table 7: Standard deviation in the two parallels, given as percent of the total value, for the mineral content of different dried samples.

% Standard deviation									
	P	**Cu**	**Fe**	**Zn**	**Mn**	**Ca**	**Mg**	**K**	**Na**
Carrot no sugar, cabinet	2,4	22	32,4	20	94	46,9	29,4	49,1	70
Carrot, 10 %, 10 min, cabinet	33,4	4,1	64	78,8	7,1	20,3	22,8	1,9	35,3
Carrot 10 %, 20 min, cabinet	9,2	33,3	32,7	83,5	59,2	7,3	28,6	4,3	37,8
Carrot 20 %, 10 min, cabinet	24,0	3,2	3,6	15,2	28,6	7,4	0,1	35,5	24,6
Carrot 20 %, 20 min, cabinet	36,0	0,0	33,5	8,3	92,3	18,2	39,0	4,2	25,1
Tomato slices, cabinet	3,8	21,4	26,4	13	0	6,1	8,7	5,7	3,9
Tomato boats cabinet	57,6	36	25,9	3,1	96	16,4	40,3	46,6	24,8
Tomato boats, tunell	11,7	35,9	10,4	2,7	0,7	8,9	7,7	5,9	14,6
Tomato slices, tunell	30,6	3,0	2,9	90,7	14,5	4,9	0,4	3,0	0,3
Onion, cabinet	7,5	34,7	0,73	12,1	19,5	2,5	7,7	10,7	1,1

The calcium content of most of the carrot samples, presented in Figure 6, was a bit lower than what suggested by MT and TFCT, but the sample pretreated with 10 % sugar for 20 minutes was close to the value presented by TFCT. The calcium content of the tomatoes was for all the samples between the values presented in MT and TFCT. The content in samples from the CD was higher than in those from the TD. The onions had a slightly higher content than what presented by the two sources.

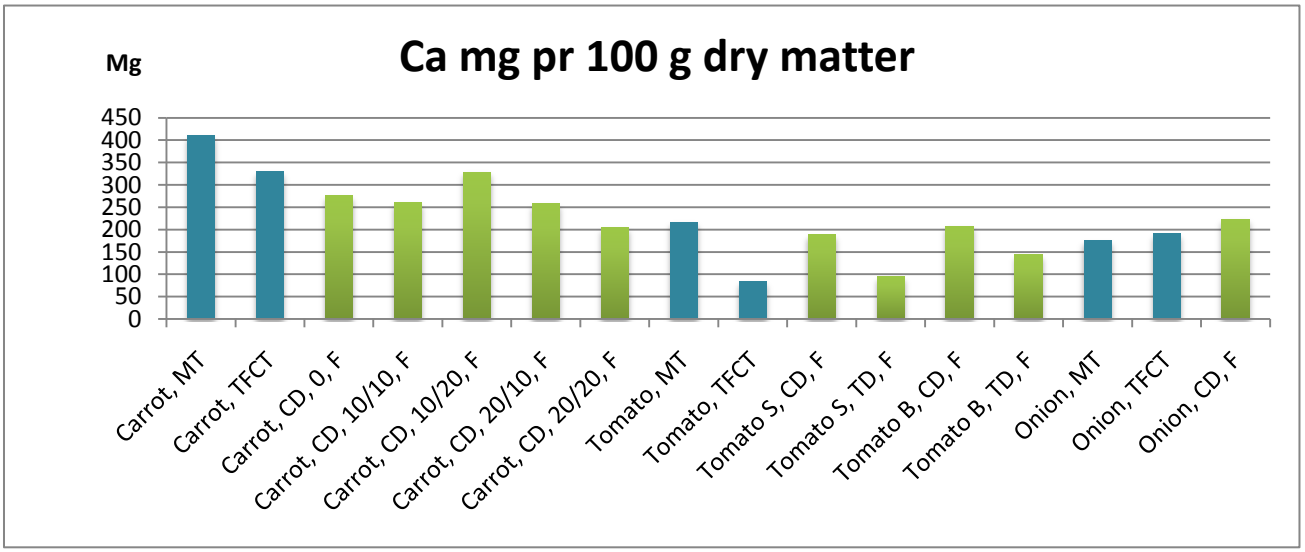


Figure 6: Calcium content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

The phosphorous content in the dried carrots was for all the samples lower than what presented in MT and TFCT, but the sample pretreated with 10 % sugar for 10 minutes was close to the given values. The tomato slices dried in the TD had a P content much lower than what suggested from MT and TFCT, while the other samples had a content closer to what the sources presented. The dried onion had a P content higher then what given by MT and TFCT.

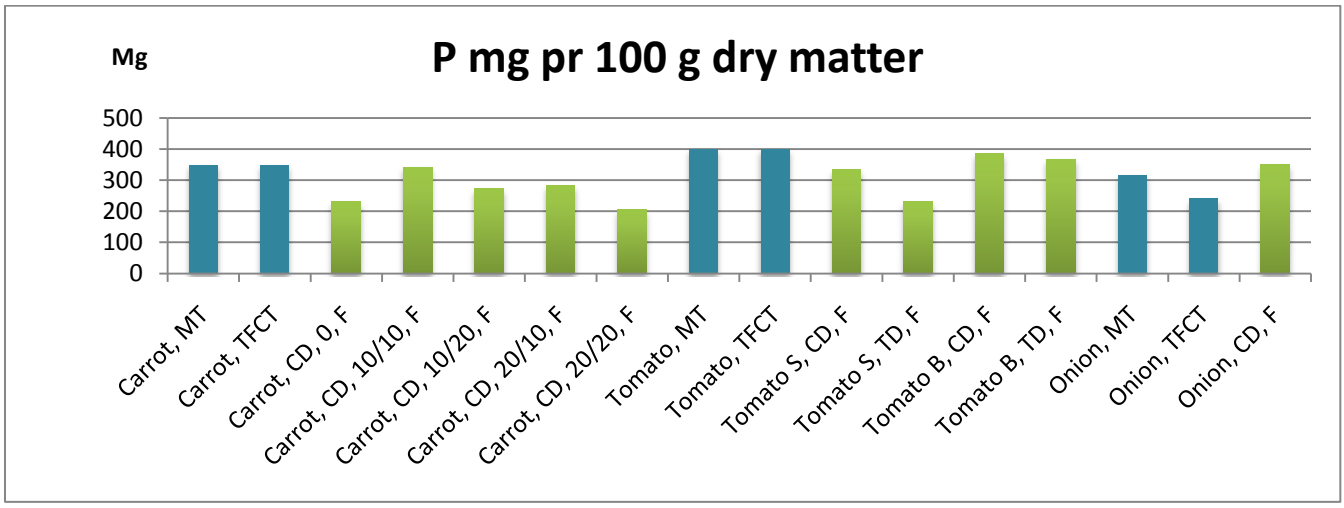


Figure 7: Phosphorus content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

The cupper content in the carrot samples varied from higher than what suggested in MT for two of the samples, while the rest of the samples had lower values. TFCT presented Cu values of 0, 0 in carrots. The tomatoes all had lower content of Cu than what presented by the sources. The onion sample had a Cu content close to what suggested by MT.

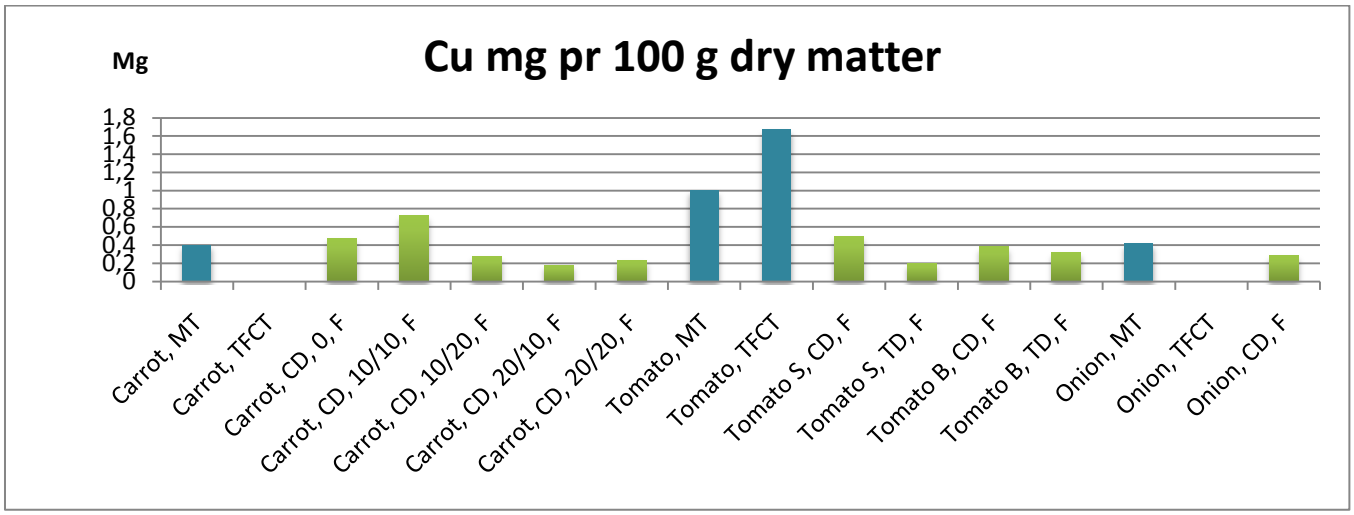


Figure 8: Cupper content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study. A Cu content of 0, 0 in carrots and onions was presented by TFCT.

The iron content of the carrots presented in Figure 9 was generally higher in the dried samples, compared to MT and TFCT. In tomatoes, the Fe values were close to what presented by MT. The onion sample had a value higher than both MT and TFCT.

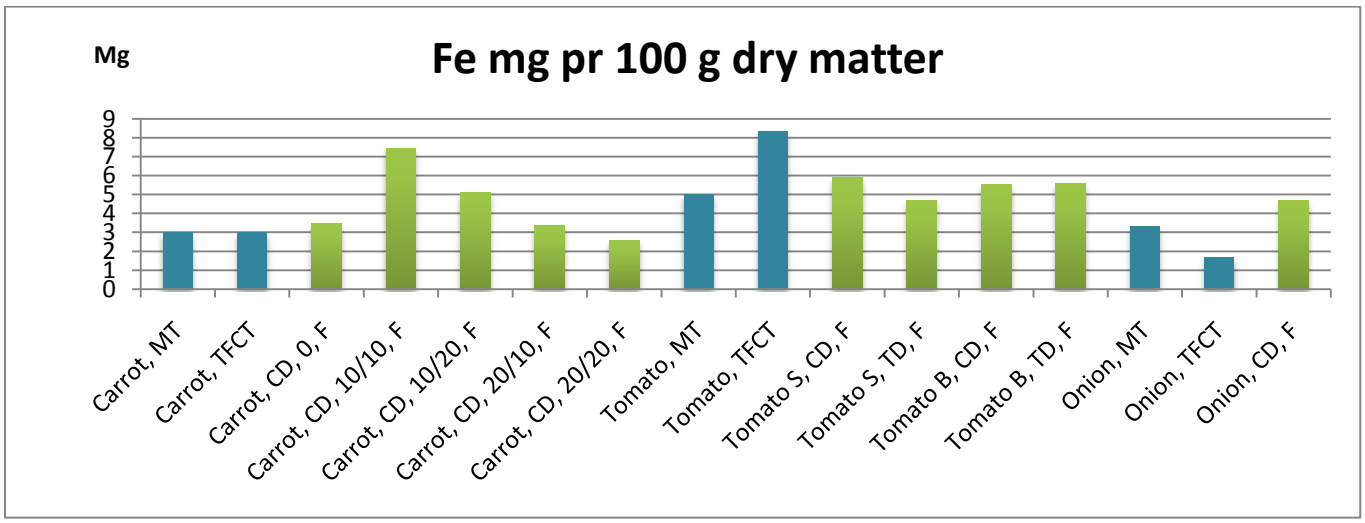


Figure 9: Iron content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

The content of zinc was quite high in carrots 10 %, 10 min, carrots 10 %, 20 min and tomato slices from the TD, compared to what presented by MT and TFCT. These three samples had high standard deviations. The rest of the samples had a Zn content close to what presented by the sources.

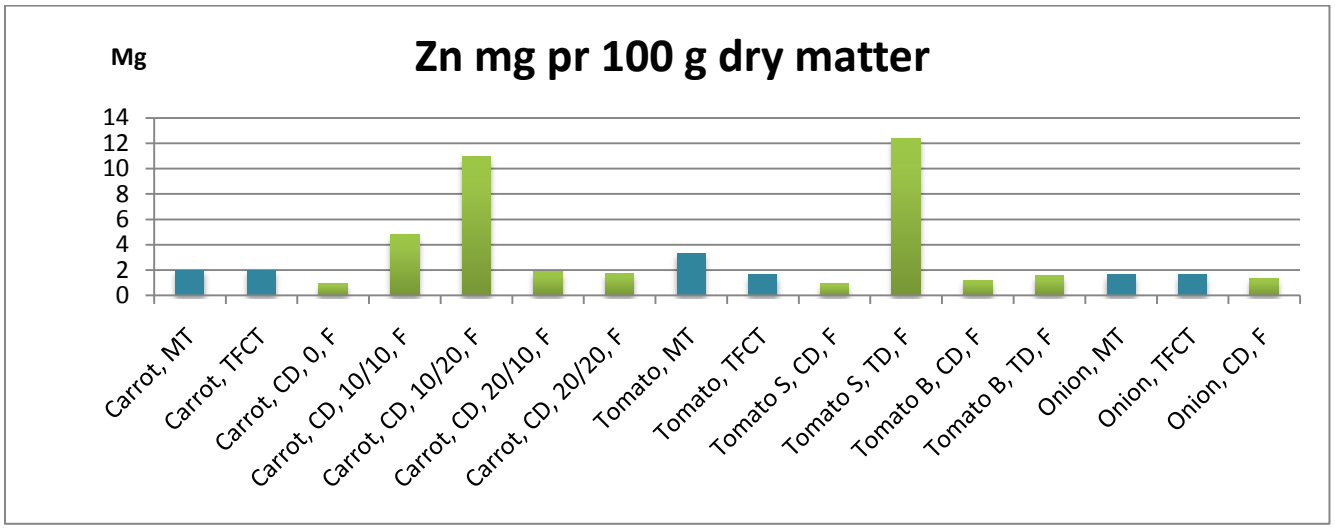


Figure 10: Zinc content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

The manganese content in the dried carrots varied a lot, and the standard deviations of some of these samples was also high. The dried tomatoes all had a much lower Mn content than what presented by TFCT. The onion samples had quite low Mn content compared to TFCT.

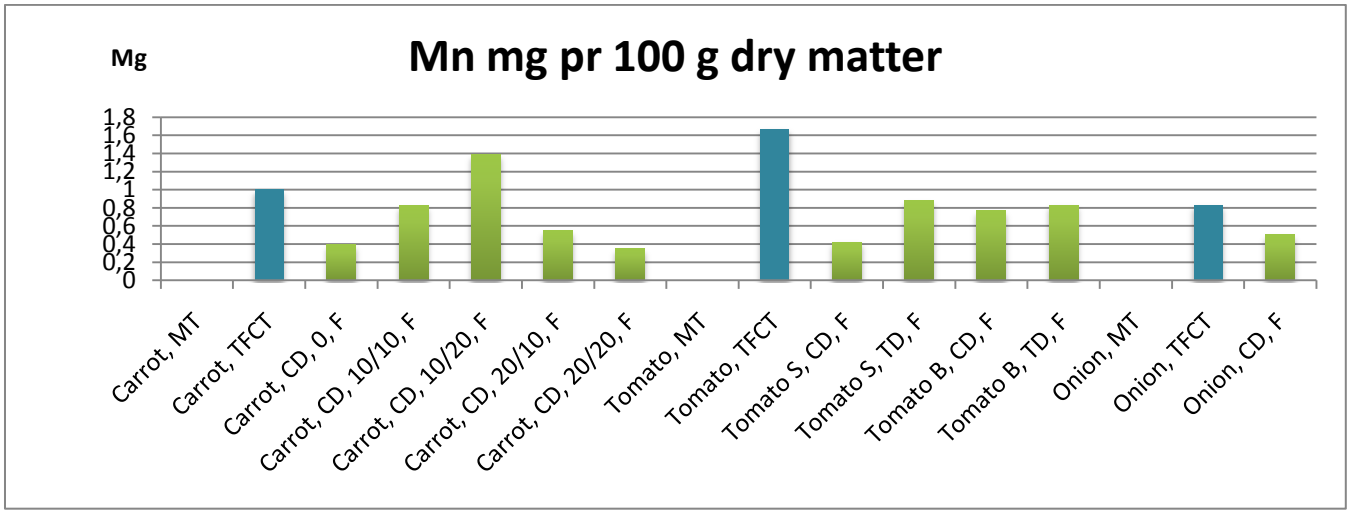


Figure 11: Manganese content in dried carrots, onions and tomatoes. MT did not present any values for Mn. Blue bars are from MT and TFCT, while green bars are results from this specific study.

The magnesium content was lower than what presented by MT and TFCT in all of the dried samples. The content between the different dried samples from the same vegetable was close to each other.

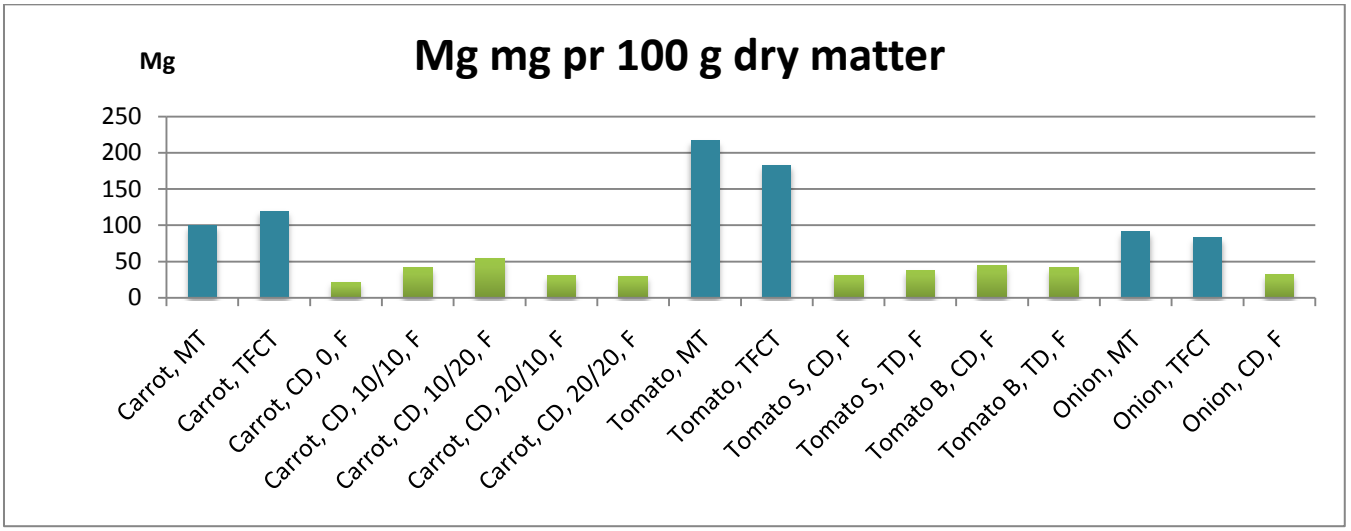


Figure 12: Magnesium content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

The potassium content of the dried carrots was all lower than what presented by MT and TFCT, and the variation between the different carrot samples was also quite high. The K content of the tomatoes was close to what presented by TFCT. The K content in the dried onion was a bit lower than what presented both in MT and in TFCT.

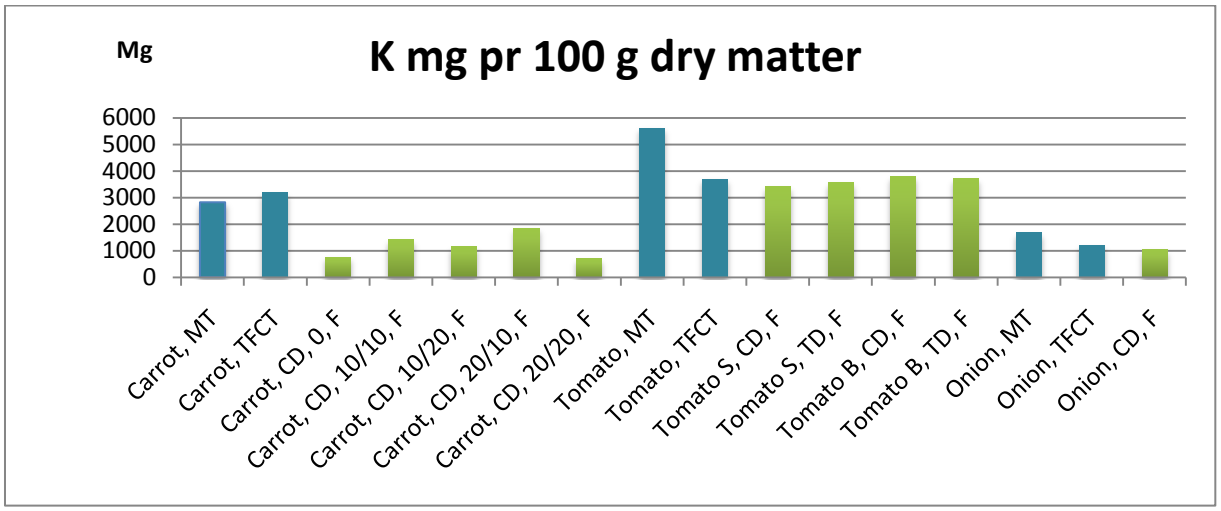


Figure 13: Potassium content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

MT and TFCT presented a great variation between the sodium content usual for carrots. All the dried carrot samples had values between those presented by the two sources. The sodium content in the dried tomatoes was lower than what was presented by MT and TFCT, and the onion had a value between what was presented by MT and TFCT.

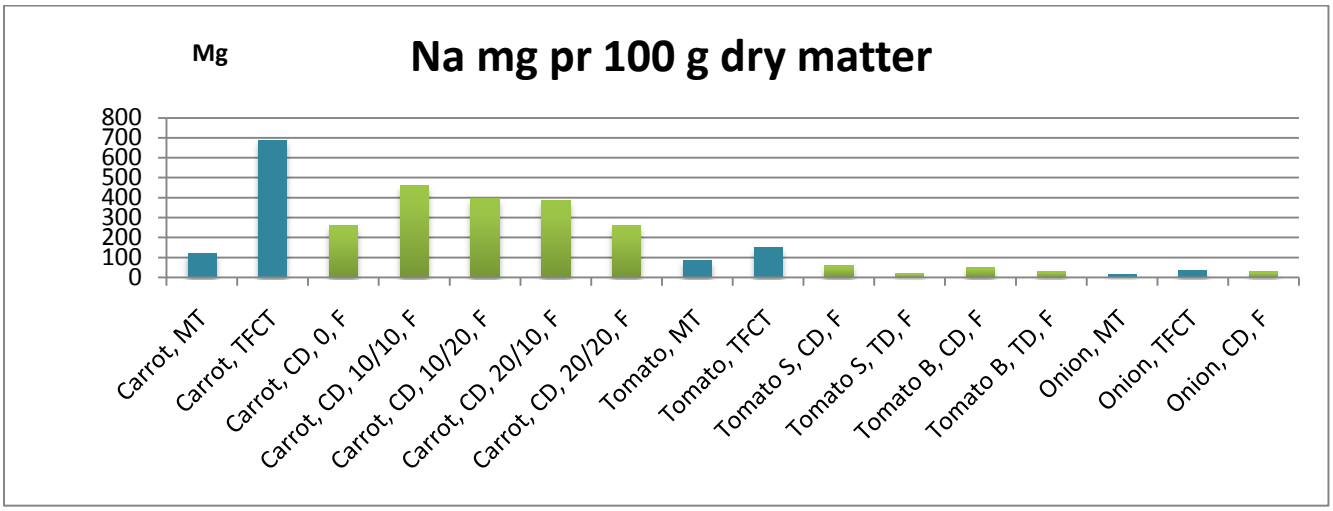


Figure 14: Sodium content in dried carrots, onions and tomatoes. Blue bars are from MT and TFCT, while green bars are results from this specific study.

4.5 PROTEINS

The protein content of the dried samples was for the carrots and tomatoes as presented in Figure 15 and 16, close to what "Matvaretabellen" and "Tanzania Food Composition Tables" presents for the fresh products, except the tomatoes from the TD. The tomatoes from the TD had a higher content compared to the samples from the CD and also compared to what presented by the sources. The dried onions had higher protein content than what MT and TFCT presents as one can see from Figure 17.

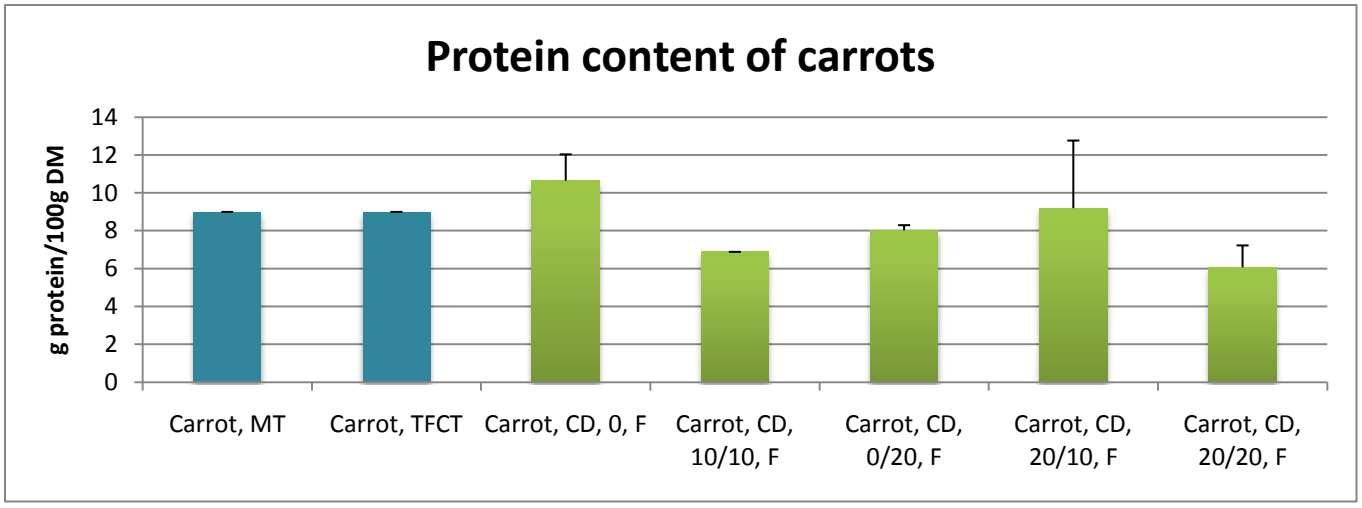


Figure 15: Protein content per 100 g dry matter in dried carrots from the cabinet dryer. The blue bars present the numbers from MT and TFCT, while the green bars shows the values detected in this specific experiment. Standard deviations are showed at the top of the bars.

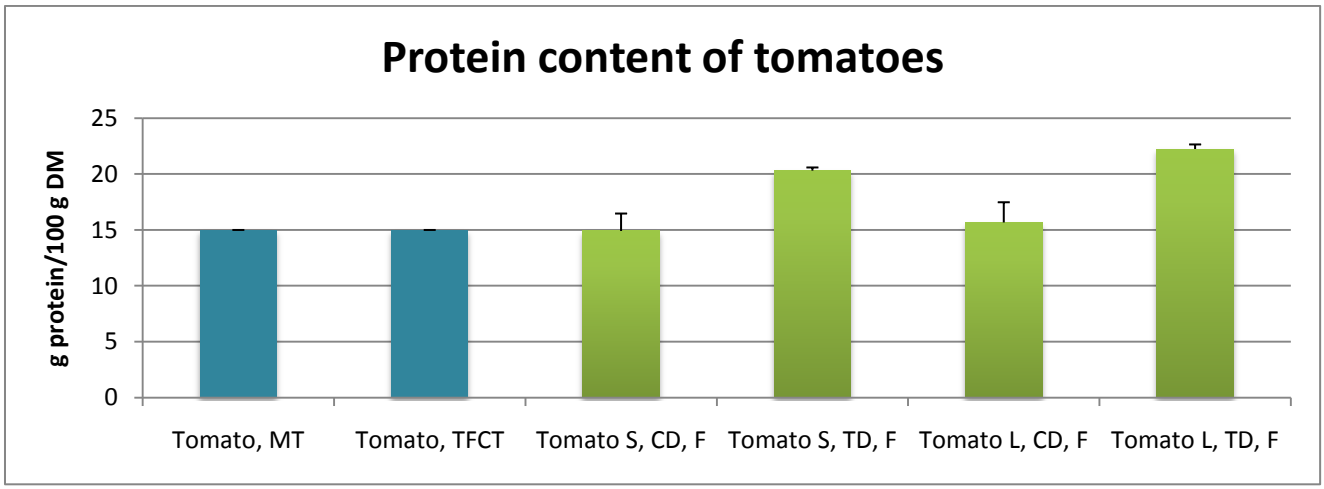


Figure 16: Protein content per 100 g dry matter in dried tomatoes. The blue bars present the numbers from MT and TFCT, while the green bars shows the values detected in this specific experiment. Standard deviations are showed at the top of the bars.

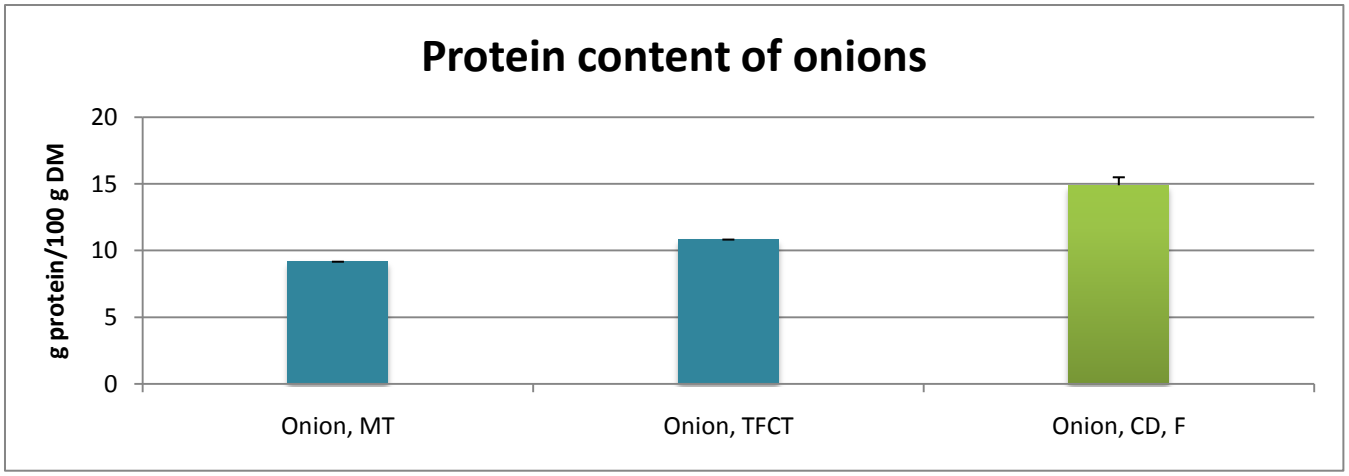


Figure 17: Protein content per 100 g dry matter in dried onions. The blue bars present the numbers from MT and TFCT, while the green bar shows the values detected in this specific experiment. Standard deviations are showed at the top of the bars.

4.6 REHYDRATION OF CARROTS

In Table 8, the numeration of the samples presented in Figure 16 to 20 is listed.

Table 8: Drying method and pretreatment method of the dried carrot samples.

Sample 1	Cabinet dryer , no sugar treatment
Sample 2	Cabinet dryer, 10 % sugar in 10 minutes
Sample 3	Cabinet dryer, 10 % sugar in 20 minutes
Sample 4	Cabinet dryer, 20 % sugar in 10 minutes
Sample 5	Cabinet dryer, 20 % sugar in 20 minutes
Sample 6	Tunnel dryer , no sugar treatment
Sample 7	Tunnel dryer , 10 % sugar in 10 minutes
Sample 8	Tunnel dryer , 10 % sugar in 20 minutes
Sample 9	Tunnel dryer , 20 % sugar in 10 minutes
Sample 10	Tunnel dryer , 20 % sugar in 20 minutes

The RR of the carrot samples presented in Figure 18, shows a clearly connection between the dryer used for production of the samples and the rehydration rate. The samples from the TD showed a higher rehydration rate compared to the samples dried in the CD. The rehydrating

ratio after 5 hours was highest for the sample without pretreatment, and the rate decreased with increasing level of pretreatment in the samples from the TD. The same trend was not discovered in the samples from the CD. Sample number 6 started with a low RR compared with the other samples from the TD, and ended with the highest ratio.

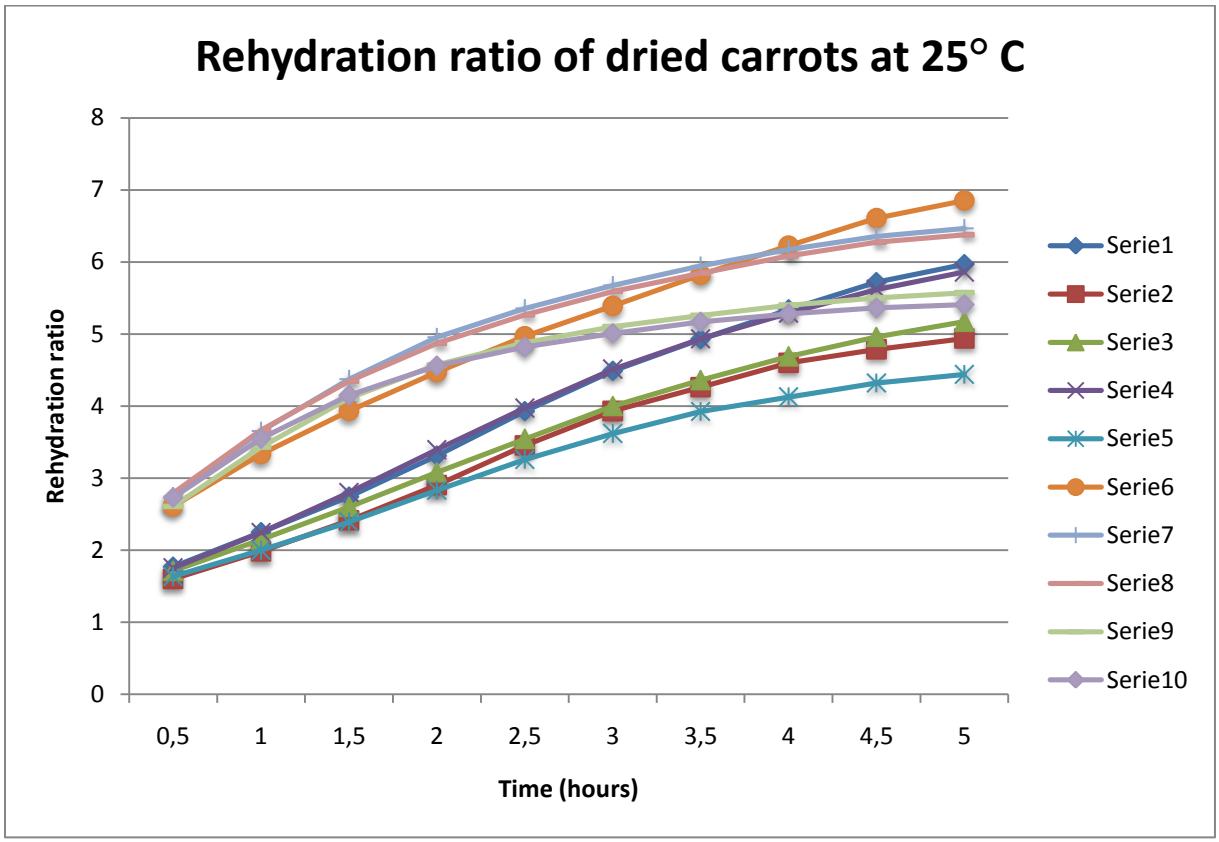


Figure 18: Rehydration ratio for ten samples of dried carrots, during a period of 5 hours and a temperature at 25 °C.

In Figure 19, pictures of the dried carrot samples are presented. The samples from the CD (Pic. 1-5) had a brighter orange color, and were less wrinkled compared to samples from the TD. The CD samples also appeared a bit more compact, then those from the TD (Pic. 6-10).

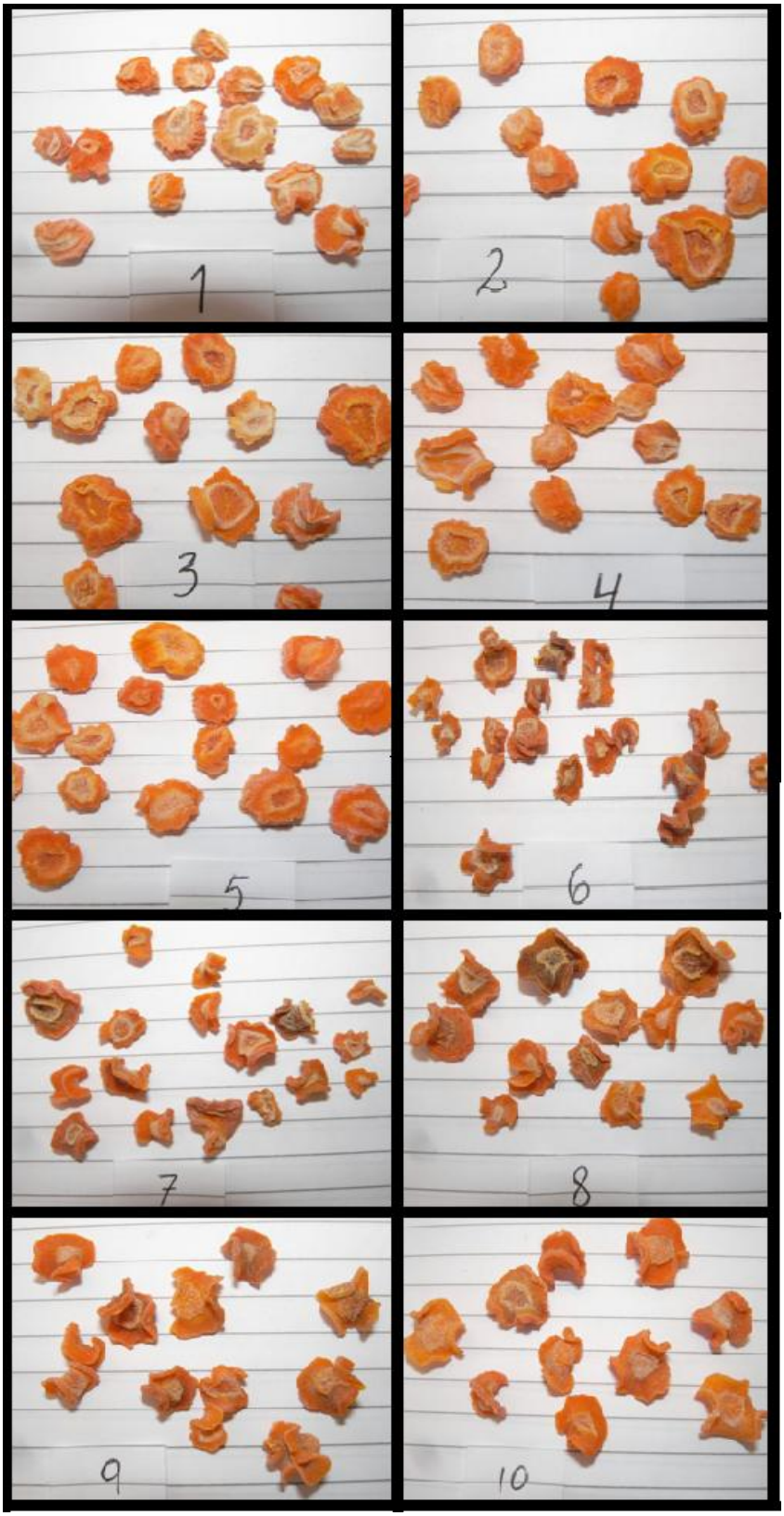


Figure 19: Pictures of ten samples of dried carrots.

Figure 20 Shows pictures of the rehydrated samples after 5 hours at 25 °C. As one can see, all the samples from the TD (Pic. 6-10) appear with a strong color, and the shape was close to what they looked like before the drying process. The samples from the CD (Pic. 1-5) were pale on one side and bright orange on the other.

Figure 20: Pictures of the ten samples after rehydration at 25° C.

In Figure 21, the RR of carrots rehydrated at 100 °C is presented. Lack of sample material from sample 1, 2, and 4 is the reason for why those were not included in the experiment. All the samples from the TD had a higher RR than the samples dried in the CD. The sample not pretreated with sugar had the highest RR, and the ratio decreased with increasing level of pretreatment. This trend was the same through the whole experiment. There were only two samples from the CD, but those samples followed the same pattern seen in samples from the TD.

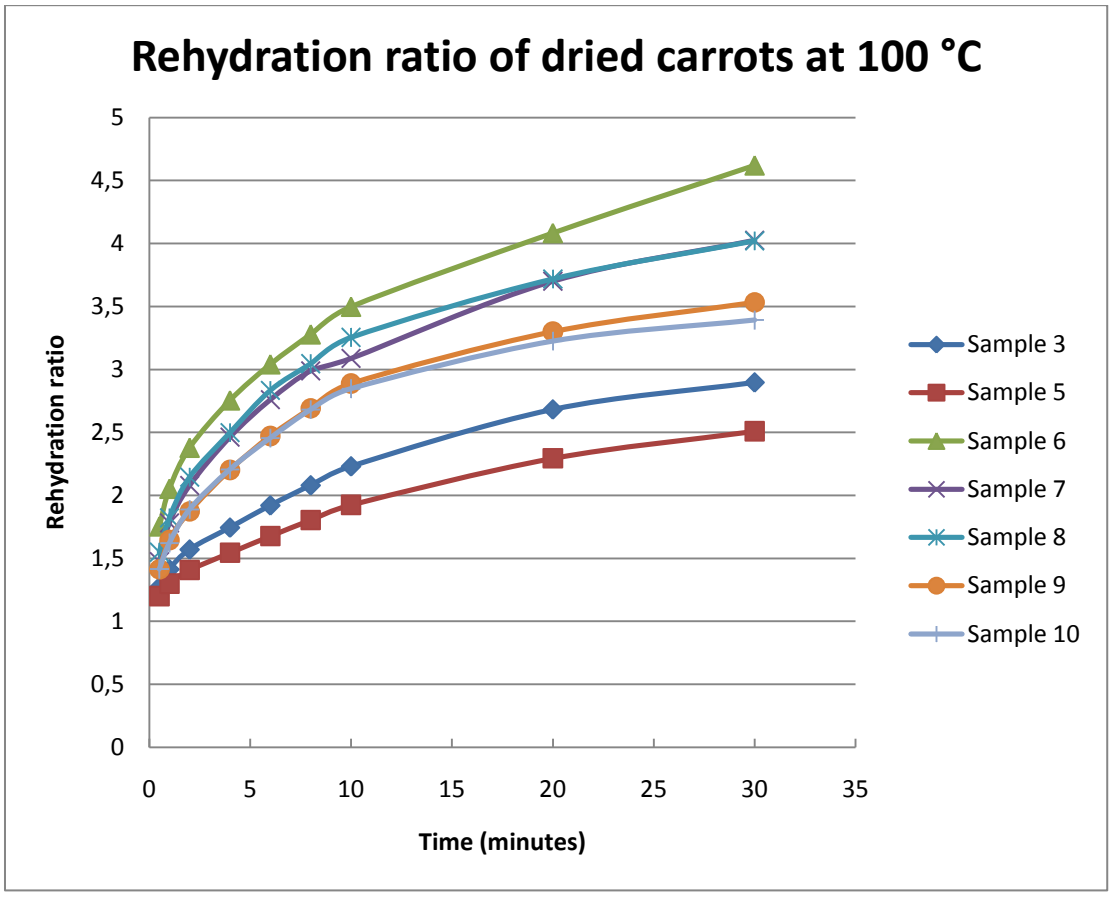


Figure 21: Rehydration ratio of seven samples of dried carrots, rehydrated at 100 °C.

Figure 22 shows the pictures of rehydrated samples after 30 minutes at 100 °C. The samples from the TD had a bright orange color, while the samples from the CD had one side of good color, and one side who were pale, as marked with red arrows.

Figure 22: Rehydrated samples of dried carrots, rehydrated at 100 °C. The red arrows points out samples with discoloration on one side visible after rehydration.

4.7 MICROBIOLOGY

The results from the microbiological detection in the different dried samples are presented in Figure 23 to 27. The amount of microorganisms that was present in the samples is given as the logarithm (Log) of the counted number.

Figure 23 shows the growth of mesophile bacteria on the PCA agar and mold and yeast at the Rose Bengal (RB) agar. In all the samples, except for carrots (10 %, 10 minutes), the growth of microorganisms was higher in the samples dried in the CD, compared to the samples dried in the TD. Statistical analyzes of the relationship between the dryer being used and microbiological activity in the samples, revealed a correlation at -0,725 between the dryer and the growth of mesophiles and the results was significant with a p-value of 0,001. It was also a correlation between the driers and growth of mold and yeast with a value of -0,743 and a p-value of 0,001. The growth in onions was generally lower than in the other dried vegetables.

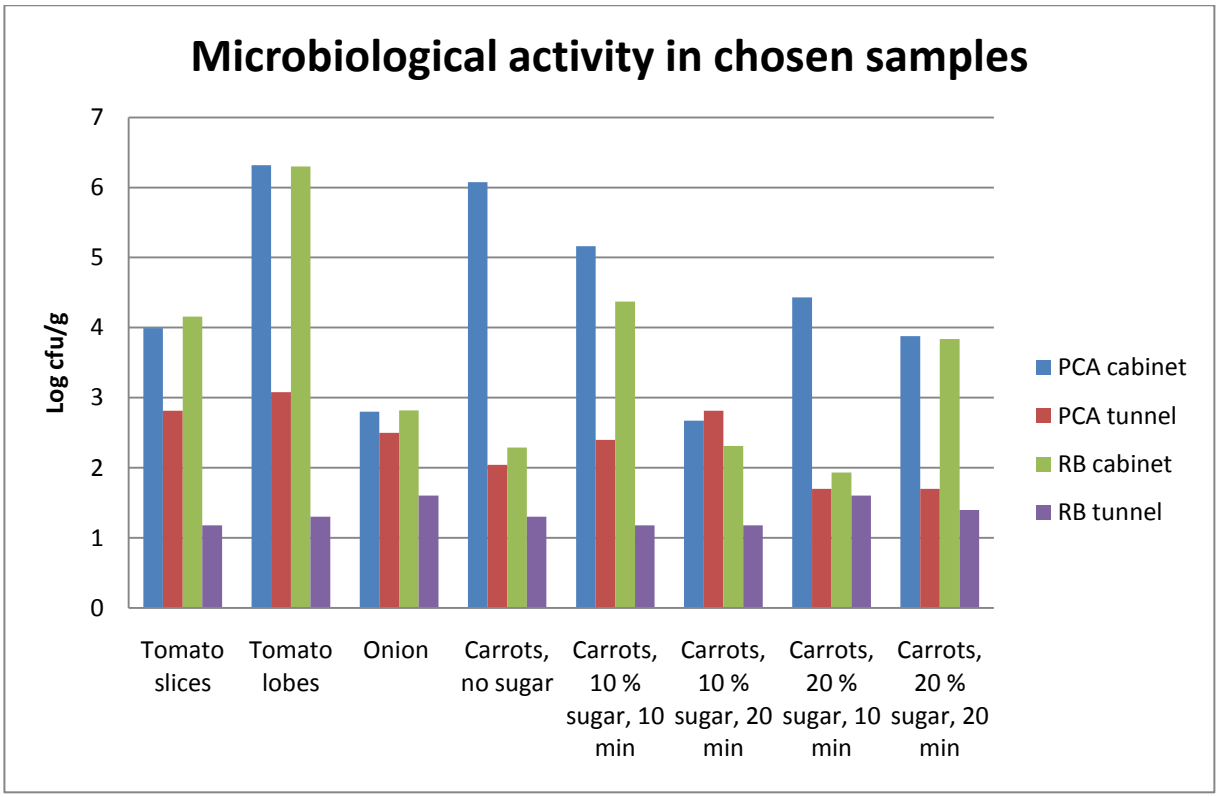


Figure 23: Microbiological activity of mesophiles and molds and yeasts in selected samples of carrots, onions and tomatoes, presented as Log number.

The microbiological activity in the carrot samples presented in Figure 24, did not show any clear relationship between the degree of sugar treatment and growth, and the results from correlation analyzes was –0,087 and the p-value was 0,629. In the samples of carrots (10 %, 10 minutes), coliform bacteria were found. The samples of contaminated carrots showed lower growth of mesophiles than the samples treated the same way, without contamination, but the growth of molds and yeast was higher in the contaminated samples.

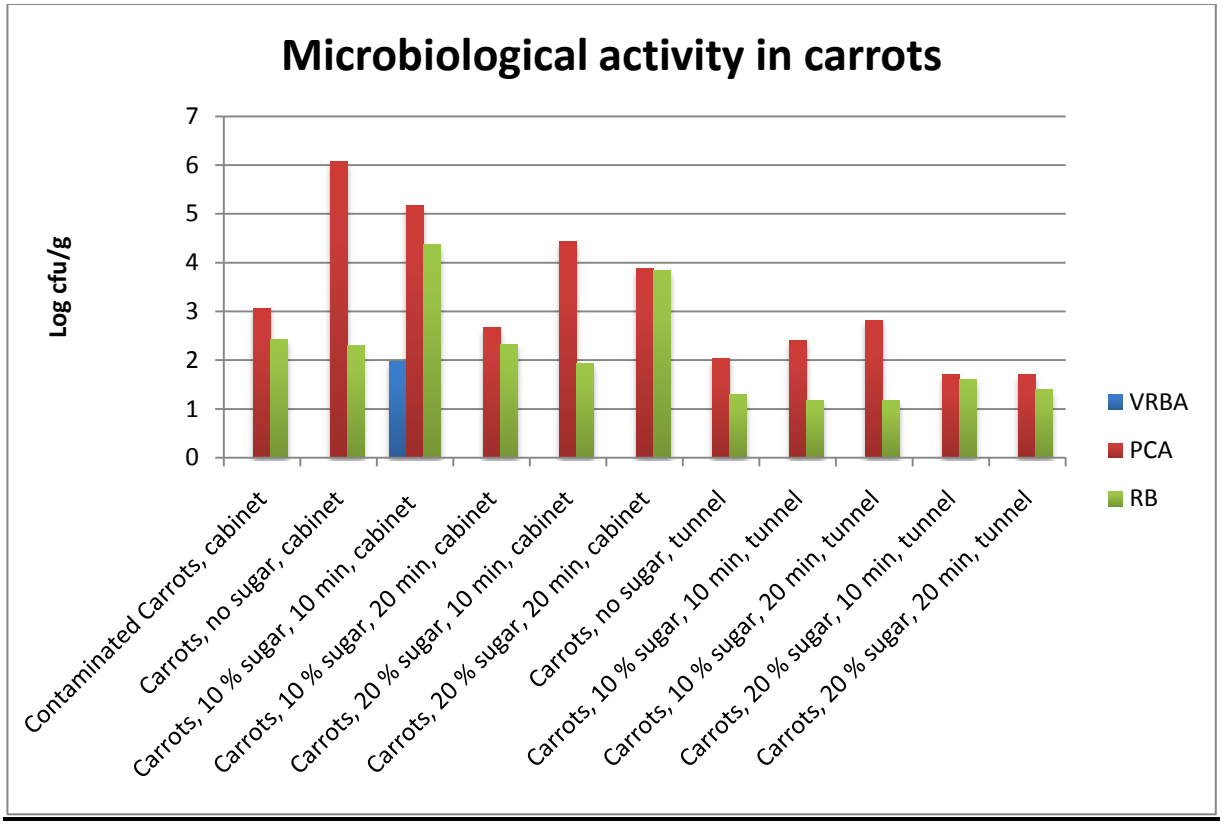


Figure 24: Microbiological activity of mesophiles, coliforms and fungi in dried carrots, presented as Log number. The contaminated sample was not freezed after drying, while the rest of the samples were freezed.

The results of microbiological activity in dried tomatoes, presented in Figure 25, did not show any correlation (-0,018, p-value 0,948) between growth and samples dried as slices or boats when both the TD and CD samples was analyzed together. Still the results show that the growth was higher in the boats compared to the slices dried in the CD. In the TD, almost the same growth was detected, both of bacteria and fungi. In the boats dried in the CD, coliforms were present. When comparing slices dried in the CD, it was less microbiological activity in

the samples that was not frozen after production. The growth in the non frozen tomato slices was the lowest of all the samples independent of dryer being used.

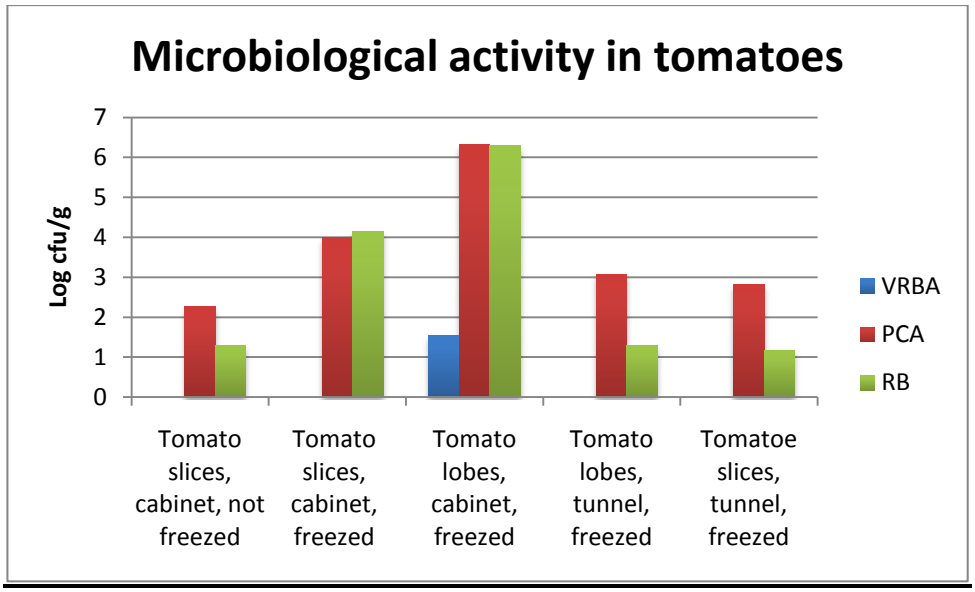


Figure 25: Microbiological activity of mesophiles, coliforms and fungi in dried tomatoes, presented as Log number.

The microbiological activity in the onion samples, are presented in Figure 26. No obvious difference in growth between samples being frozen or not was found. The activity in the samples dried in the TD was lower than in samples dried in the CD.

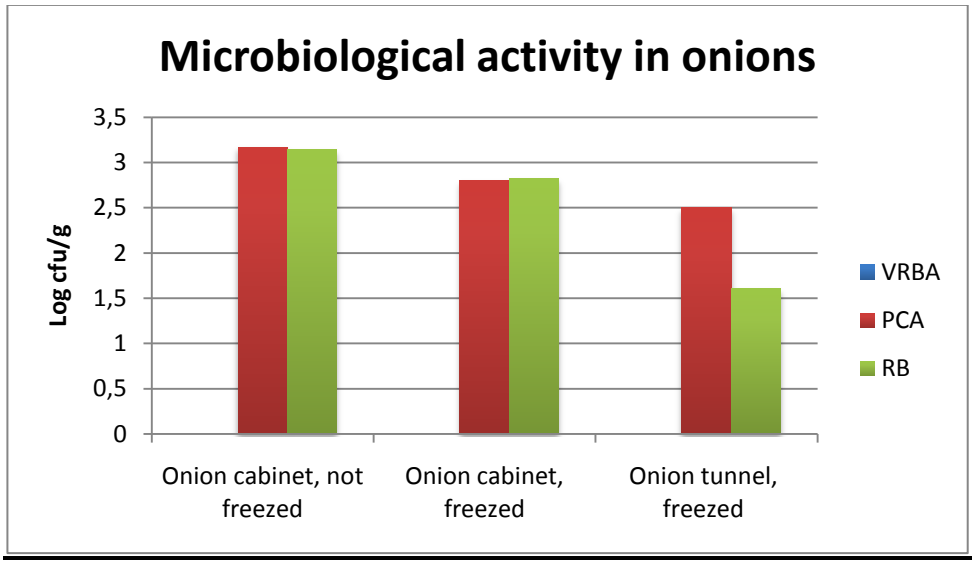


Figure 26: Microbiological activity of mesophiles, coliforms and fungi in dried onions, presented as Log numbers.

The presence of mold and yeast in the dried samples is presented in Table 9. It was found mold in all the samples except the tomato boats from the CD.

Table 9: Presence of mould and yeast in dried samples of onions, tomatoes and carrots. (*) indicates that the organism was present, and (-) indicates that the organism not was present in the sample.

	Mold	Yeast
Onion cabinet, not freezed	*	-
Onion cabinet, freezed	*	-
Onion tunnel, freezed	*	-
Tomato slices, cabinet, not freezed	*	-
Tomato slices, cabinet, freezed	*	*
Tomato boats, cabinet, freezed	-	*
Tomato boats, tunnel, freezed	*	-
Tomatoe slices, tunnel, freezed	*	-
Contaminated Carrots, cabinet, not freezed	*	*
Carrots, no sugar, cabinet, freezed	*	*
Carrots, 10 % sugar, 10 min, cabinet freezed	*	*
Carrots, 10 % sugar, 20 min, cabinet, freezed	*	*
Carrots, 20 % sugar, 10 min, cabinet, freezed	*	*
Carrots, 20 % sugar, 20 min, cabinet, freezed	*	*
Carrots, no sugar, tunnel, freezed	*	-
Carrots, 10 % sugar, 10 min, tunnel, freezed	*	*
Carrots, 10 % sugar, 20 min, tunnel, freezed	*	-
Carrots, 20 % sugar, 10 min, tunnel, freezed	*	-
Carrots, 20 % sugar, 20 min, tunnel, freezed	*	*

As one can see from Figure 27, there was a positiv relationship between MC and the growth of microorganisms. The correlation between the two variables was 0,685 and the p-value was 0,000.

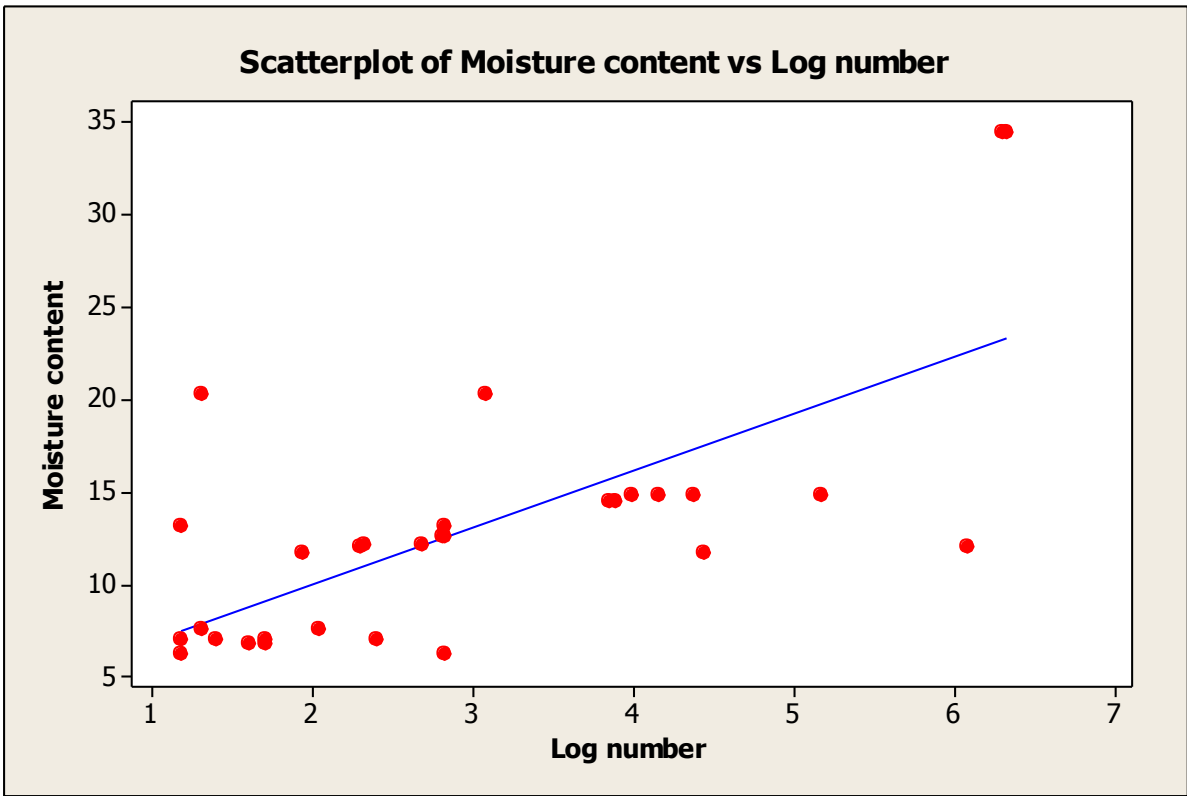


Figure 27: Scatter plot of the relationship between moisture content of the samples and the log number from the microbiological analyses. The log numbers was those registered at the PCA and RB agars.

5 DISCUSSION

5.1 MOISTURE CONTENT

The MC was significant lower in all the samples from the TD, than those from the CD. This was the same for all the different vegetables. This was probably due to higher temperatures and higher velocity of the airstream (AV) through the TD, compared to the CD. (Sharma et al. 2009) showed that drying crops with a TD is more efficient than with a CD. The results obtained in this particular study supported (Sharma et al. 2009)s results.

The MC of the tomato boats from the CD where 34,44 %, which was quite high compared to the 10,45 % presented in (Gallali et al. 2000). The consistency was soft, and after short time storage in a closed plastic bag, they where spoiled, with massive growth of molds. The size of the boats could be the reason for why the insufficient drying was seen. The tomato slices from the CD had a MC of 14,8 % which was close to what found in the other vegetables of this study, dried in the CD. Anyway, it was much higher than results from (Gallali et al. 2000), who reported 5,05 % MC in the dried slices.

The tomatoes dried in the TD had significant lower MC, than those from the CD. The boats still had a MC of 20,27 %. The (USDA 2010)s standard reference value for sun dried tomatoes, provide a MC of 14,56 %. Increasing the drying time of the tomato boats in the TD could maybe given boats with lower MC. The slices had a MC of 13,19 % and this value was a bit higher than the value of 10 % presented in (Sharma et al. 2009) as necessary to prevent deterioration of the products, but lower than the value from (USDA 2010).

The results for dried tomatoes showed that drying larger pieces of material could be a challenge, especially in the CD. The weather needed to be very dry and stable during the drying period, and the boats should not be too big. None of the samples reached a MC low enough to satisfy (Sharma et al. 2009)s MC of 10 % necessary for a safe product. Anyway, the value for a safe product includes all the deterioration processes in the products. As long as the MC is low enough for preventing microbiological growth, and right packaging material that not allows oxygen and light to react with the products are used, the shelf life of the products could still be long. Further storage experiments are necessary to investigate the storage potential of all the different products.

(Sharma et al. 2009) describes a MC of 4 % to be the safe value of dried onions. The dried onions from the TD had significant lower MC than those from the CD The samples from the CD had a MC of 12,5 %, while samples from the TD had a MC lower than 6 %, which was close to the suggested value of 4 %. The study by (Gallali et al. 2000) showed a MC of 13,10% in dried onion slices, which was high compared to (Sharma et al. 2009)s value. The result from this particular study showed lower MC than those presented by (Gallali et al. 2000) in samples from both of the driers, but specially in the samples from the TD. As mentioned for the tomatoes, also shelf life studies with onions should be performed to study if right packaging material could make the quality of the product acceptable although the MC was higher than the safe value presented in (Sharma et al. 2009).

As described by (Sharma et al. 2009), dried carrots could have a MC of around 5 % to be safe. The samples from the CD had all MC between 12 and 15 %, which was quite high compared to the suggested values. Samples from the TD had significant lower MC, and the values were between 6,25 % and 7,5 %. This was close to what was expected compared to the numbers from (Sharma et al. 2009), but lower than the MC of 10 % presented by (Lin et al. 1998). The fact that most of the samples was pretreated with sugar, does that the shelf life could be longer, due to the positive conserving properties in the sugar. Together with right packaging material, the dried carrots might have a shelf life acceptable for the consumers.

During the drying experiments, it came through that weather conditions strongly affected the quality of the products. When drying tomatoes in the TD, the weather conditions were unstable, with high RH and some rain. After 24 hours in the dryer the products was quite dry, but mold could be seen on many of the products, both slices and boats. This showed that the process was very vulnerable and a lot of work and products could get lost, if the weather is not optimal. The fact that one could see mold after short time means that it was growing very rapid and toxic compounds from the mold could be present. Regarding food safety, this would be a big challenge.

Carrots and onions gave fewer problems regarding the drying process. No growth of mold was seen by visual inspection.

5.2 ASCORBIC ACID DETECTION WITH HPLC

The L-ascorbic acid (L-AA) content of the different vegetables, where all below the values presented by the Norwegian (MT) and Tanzanian (TFCT) food composition tables. This was as expected since the products had been exposed to both heat and oxygen.

There was no L-AA in the samples of dried carrots. According to MT it is usual to find around 2 mg L-AA in fresh raw carrots and 20 mg per 100 g dry matter (DM). The dried carrot samples was first sliced, blanched, and then dried, and all those unit operations influences according to (Damodaran et al. 2008) the degradation of L-AA by heat treatment, exposure to oxygen and light. In combination with the large surface exposed to the degradation factors, this was probably the reason for why there was no L-AA found in the samples.

MT suggests that L-AA content in onions is 6 mg in raw onion, which gives 50 mg per 100 g DM. The content in the dried onions was highest in the samples dried in the CD with 14, 87 mg/100 g DM, compared to 9, 03 mg in the samples from the TD.

When it comes to the tomatoes, MT gives an L-AA content of 17 mg in raw product, and this gives 283, 3 mg per 100 g DM. The samples of sliced tomato from the CD, was the one with the highest content. The boats from the CD, was of so bad quality, due to incompletely drying, so these were not tested. The slices dried in the TD were those with lowest L-AA content. The boats from the TD showed higher amounts of L-AA than the slices from the TD. The boats had a smaller surface exposed to the surface, compared to the mass, than the slices. This could lead to the fact that more of the L-AA was protected inside the product, less exposed to the degrading factors.

When one look at the difference between the two driers, it seems like the products from the TD had less remaining L-AA in the dried products. As seen from the moisture measurements, those samples were dryer than those from the CD, and the temperature could have been higher during the drying period. This was probably the reason why more L-AA was degraded.

The statistical analyses of the relationship between the driers being used and the content of L-AA did not show any significant correlation. The reason for this could be that there were too few samples to get a clear result.

5.3 VITAMIN A ANALYSIS

In this study, there was no time and resources to analyze the content of Vitamin A or β-carotene. Still the remaining content of this vitamin is very important in the dried products in this specific study, since the consumers live under conditions where deficiency of vitamin A is common. Therefore experiences from the results of earlier studies of degradation in different fruits and vegetables during drying, could give an indication to how the drying process could affect the content of the products dried in this study.

As mentioned in chapter 2.7.7., (Bechoff et al. 2009) described a total carotenoid loss of 21 % in solar dried sweet potatoes, while (Ndawula et al. 2004) described a β-carotene loss of 53,37 % in cowpea leaves. The cowpea leaves was probably much thinner than the samples of carrots, tomatoes and onions, so degradation might have been higher in the leaves compared to the vegetables. Degradation close to what seen in the sweet potato could maybe be more realistic for the vegetables dried in this specific experiment.

5.4 MINERALS

After burning the samples before the Atomic Absorption spectroscopy, too much of the carbon was still remaining. This was probably because the samples in the furnace were placed to close. The standard deviation of the two parallels of the samples was generally quite high, so the probability of these results being correct was rather low.

As described in (Nes et al. 2004) the mineral content of a vegetable reflects the soil it has been growing in. Comparing the amounts of minerals from this study, with the numbers presented in MT and TFCT directly will therefore not be right. Instead the results from the mentioned tables, was used as a guide for about which amounts of the minerals, that could be present in the specific product.

The reference values from MT and TFCT are showed as blue bars together with the results from this study, to easier could compare the values. It is important to understand that those numbers are not from this study, although they are presented in the result figures.

The amount of calcium in the different vegetables was in the carrot samples a bit lower than those presented from MT and closer to those from TFCT. Except from the soil quality, the blanching process could have contributed to some loss to through leakage to the blanching water. The values for tomatoes varied quite much between MT and TFCT, and the samples from the drying experiment had values between those from the two sources. It was still a considerable variation among the samples from the TD and the CD. A reason for this variation could be that processing took place different days, so the tomatoes bought at the marked could have been grown in different areas with unlike soil conditions.

The onions had a calcium amount a little bit higher than those presented by the sources, and this might be caused by the soil quality at the growth area.

The amount of phosphorus in the dried carrots was all lower than those presented in MT and TFCT. The variation between the different carrots did not show any obvious pattern concerning amount of sugar from the pretreatment. The tomatoes were closer to the values presented in the sources, except from the slices dried in the TD. A reason for this could be that sample material from this product contained parts of tomatoes less rich in phosphorus. The onions had slightly higher values than those presented from MT and TFCT.

The copper content of the dried carrots was for some of the samples higher than values from MT, while other was lower. No obvious pattern between the samples could be detected. The dried tomatoes also showed low values compared to the sources, and especially in relation to numbers from TFCT. Also onions had a value lower than presented in MT, but higher than TFCT, which numbers says that no copper is present in onions.

The iron content of dried carrots was all higher than numbers presented from MT and TFCT (except carrots 20 %/20 min), which presents the same values. Especially carrots pretreated with 10 % sugar for 10 minutes had a very high amount. The standard deviation for this sample was very high, so one of the values obtained was lower than those from the sources. Wrong readings, or contamination of one of the samples, could have been the reason for the big difference from the rest of the samples. Values of iron content from the experiment with dried tomatoes, was all close to values presented by MT, and onions had a higher content than both sources. The high value of all of the samples means that they could be a good source for iron in the diet.

For all the samples, zinc content was quite close to the numbers presented by MT and TFCT, with the exceptions of carrots pretreated with 10 % sugar for 20 minutes and tomato slices from the TD. Both these samples had parallels with a wide standard deviation, so the results showing high values could be wrong, considering the more equal numbers from the other samples.

For all the dried carrot samples, big variations of manganese content between the samples and between the values presented in TFCT could be seen. The values in tomatoes were lower than those presented by TFCT, but closer among the tomatoes. The dried onions contained less manganese than what the source presented for the product.

The magnesium values of all the dried products were lower than values presented by MT and TFCT, but quite close to the other dried products from the same vegetable.

Potassium values in dried carrots was all lower than both presented by MT and TFCT, and there was no obvious pattern in the values among the carrot samples. Samples of dried tomatoes had all a potassium content close to what presented by TFCT, but a bit lower than numbers from MT. The sample of dried onion was also close to the value from TFCT, but content presented by MT was higher.

Dried carrots had a quite high amount of sodium compared to the other vegetables. This was the same results as TFCT presents in their tables, although the numbers from TFCT are a bit higher than those found in the dried carrots. MT reports lower sodium content than those found in the carrots. For both dried tomatoes and onion, values are close to those presented by MT.

Looking at all the samples together, it was clear that considerable variations from the values suggested by MT and TFCT was present, still the values was relatively close to what the sources suggested as a usual mineral content for the respective vegetables.

5.5 PROTEINS

The protein content of the dried products was generally good compared to what presented by MT and TFCT. The tomatoes dried in the TD and the onions had higher values than those presented. Why the tomatoes from the TD had a higher value than those from the TD is not

known, but different raw material or tissue from different part of the tomatoes could be a reason. The high temperature could lead to higher degree of denaturation of the proteins, but the amount of nitrogen which is what measured by the Kjeldahl method should still be the same. As (Mazengo et al. 1997) presented, many people of rural Tanzania eats to little proteins. The dried product could therefore contribute to raise their daily protein intake. Anyway, the proteins from vegetables is not of the same high biological quality as proteins from animal sources (Nes et al. 2004), but still it contains some of the essential amino acids.

5.6 REHYDRATION

The RR from the samples rehydrated at 25 °C showed that the samples dried in the TD had a higher RR than those pretreated in the same way, but dried in the CD. The initial stages of the rehydration were also faster in samples from the TD. As presented earlier, (Fellows 2000) presented the RR for carrots to be 7,0.

By comparing the samples from the different driers, but with the same pretreatment, the samples followed a pattern where the sample without pretreatment reached the highest ratio, and the ratio decreased with increasing degree of pretreatment. This was the same results as reported by (Aktas et al. 2007). One possible reason for why the carrots from the CD performed a slower rehydration rate could be the more compact shape of the dried products. Samples from the TD where less dense, and had a larger surface where water could permeate the cells. The pattern of rehydration rate found in samples from the TD could not be seen in the samples from the CD. It could be that a longer rehydration time could have given other results, since the products did not reach the same values as those from the TD.

Another reason for the higher rehydration rate from the TD dried samples could be the low initial MC of these samples. The mean MC of the TD samples was 6,89 %, and in the samples from the CD it was 13,04 %.

Because of too little samples left, it was not possible to get a rehydration rate of the products from sample number 1, 2 and 4 for rehydration at 100 °C. The rest of the samples showed the same tendency as those rehydrated at 25 °C. Initial drying rate was faster in the samples from the TD, and the different pretreatment gave the same order as seen before. The rehydration rate did not reach the same high values as those rehydrated at 25 °C, but this could be due to

shorter rehydration time. The appearance of the rehydrated products was also a bit more wrinkled, probably also because of the shorter rehydration time.

None of the samples reached a RR of 7,0 as presented by (Fellows 2000), but as mentioned earlier, the drying and rehydration methods could influence the RR of the products.

In the end of the rehydration experiment a non scientific sensory evaluation was performed by three of the participants of the project. The main question was if the sugar treatment was so obvious, that the samples not were suited to use in cooking. There was an agreement that the taste of sugar was not very apparent and the slightly sweeter taste was experienced as good. The consistency of the products was well accepted for use in cooked meals. The taste was a bit watery and tame.

The taste of the samples rehydrated at 100 °C was less watery than those rehydrated at 25 °C, and the consistency was good. This showed that the products could be well suited for use in meals that are cooked for about 30 minutes or more.

5.6.1 Appearance of the dried carrots

The dried carrots from the CD generally looked a bit more compact than those from the TD. When considering the appearance of the samples with focus on the different pretreatment, it seemed like the samples pretreated with 20 % sugar solution for 20 minutes was clearly less wrinkled than those without any pretreatment, both in the samples from the CD and the TD. The color of the dried carrots was deep orange in all the samples, but the samples from the TD showed pieces with darker color and a bit more grey shade.

After rehydration, all the samples from the CD showed a pale color on one of the sides, marked with a red arrow in Figure 22. Why this came, and only in the samples from the CD is not known. It was not possible to see from the pieces if the pale color were on the surface placed on the tray or the surface facing the air above the trays. One possible reason could be that the moisture inside the drier not have been removed rapid enough during the drying period, and condensed inside the dryer during the cooler nighttime. In this case, some of the moisture could have been taken up by the surface of the carrots, making it moist for a longer period. Another possible reason could be bleaching from sun rays, not stopped by the surface

of the dryer. The orange color comes from the carotenoids, and it is possible that the bleaching could have affected the vitamin A activity in the samples. Light and oxygen exposure could as (Damodaran et al. 2008) describes degrade the β-carotene. This bleached effect on the samples was not found until the samples where rehydrated, and it was not possible to dry new samples to investigate if there was a problem with this one batch, or a problem common in the CD.

The samples from the TD did not show any sign of paleness on one side.

5.7 MICROBIOLOGY

In this study, the production routines was performed as clean as possible, and with equipment available when producing dried products in rural areas. Producing products in the locals used in this experiment was probably a bit more hygienic than what is realistic in the small villages.

After the products were dried, half of the samples were put in a freezer, while the rest of the samples were stored in closed plastic bags. Plastic glows were used while handling the dried material. The plan was to study if there was any difference between the growths of microorganisms after different storage and if the different driers affected the growth. Because of challenges with some of the analyses performed in Tanzania, many of them were repeated in Norway. There was therefore not enough sample material left of most of the unfrozen samples, to perform microbiological experiments on these.

The results from the experiments showed that even under quite controlled conditions, some of the samples were contaminated with coliform bacteria. Both of these samples were produced in the CD. It is possible that the assumed higher temperature in the TD was high enough to kill the coliform bacteria. Since there were so few samples with coliforms present, it was not possible to see any clear relationship here, and the contamination could have taken place during handling and packaging of the dried material. It is also possible that none of the other samples had been contaminated at all, and the dryer being used does not affect the growth of coliforms.

The total growth of microorganisms in the two driers showed that there was a significant correlation between the dryer being used and the amount of microorganisms in the dried samples. These results showed that the drying condition in the TD was favorable for producing a product with fewer microorganisms, and again higher temperature could be the reason. Anyway, the results did not tell anything about which mesophiles growing in the sample, so it could be a chance that some of the bacteria growing in samples from the TD was pathogens, while those from the CD was not. A more specific experiment is necessary to reveal this.

(Fellows 2000) describes a pasteurization temperature for fruit juice of 65 °C for 30 minutes, to inactivate enzymes and destruction of spoilage microorganisms. The temperature inside the TD could as (Hossain & Bala 2007) described reach a temperature of 66 °C. It is therefore possible that the lower growth of microorganisms is a result of the high temperature. The temperature conditions in the dryers is not stable enough to conclude that the temperature conditions of the TD always will reach a temperature high enough to destruct the microorganisms.

Another possible reason for the higher microbiological growth seen in samples from the CD is that those samples used longer time to dry. That could have made it possible for microorganisms to grow over a longer time before the water activity was low enough to prevent further activity. To better understand if it was the higher temperature in the TD that killed present organisms or better growing conditions for a longer time in the CD, it could have been interesting to analyze the raw material before drying. If the number of microorganisms was higher before drying, it could be the temperature that reduced activity, and if the number was lower, it could have been the positive growing conditions that were the reason. When planning the second experiment of microbiological analyzes in Tanzania, the raw material was to be tested, but since it was problems with completing that analyze, that was not done.

The microbiological activity in the carrot samples did not show any clear pattern between the degree of sugar treatment and growth. One could believe that higher sugar content preserved the samples when more water was bound to the sugar, and solute sugar in the resisting water increased the osmotic pressure for the bacteria, but that was not seen in these samples. The samples contaminated with feces did not have higher growth of microorganisms, and no

coliforms were detected. A reason for this could be that it took many weeks between the samples was produced and the samples were analyzed, so some bacteria could have died.

The contaminated samples did not have any growth of coliforms, and the growth of mesophiles was lower than in the other sample without sugar treatment from the CD. The growth of mold was about the same as for the mentioned sample. If the microbiological experiments had been performed in a shorter time after drying it is possible that more activity from coliforms had been detected. The water used for contamination was to be tested at SUA, but problems with the experiment made that impossible and the water could not be brought back to Norway. Because of this, the amount of microorganisms in the water is not known. It could also be that the feces used for the contamination was to dry, so no coliforms was alive.

The tomatoes were produced in two varieties, one cut as slices and one as boats. The different shape would influence the drying time, and how much moisture that was retained within the products.

The results from the analyses of the tomatoes showed that the sample not stored in the freezer was the one with lowest microbiological growth. When freezing the products, moisture in the air inside the bag will start to condense because colder air cannot keep as much water as hot air. This moisture could then freeze on the surface of the dried product. When the product are thawed to room temperature again, the ice on the surface will melt, and the MC of the surface will increase. This could lead to better growing conditions for microorganisms.

The tomato boats from the CD had a growth much higher than the rest of the tomato samples. The MC of these samples was very high, and this was probably the reason for why microorganisms had better growing conditions.

The onion samples did not have so much growth compared to the other vegetables. The difference between the dryers being used and whether the samples were frozen or not, wasn't very big.

Most of the samples had growth of mold, and many of them also yeast. The only sample without mold was tomato boats from the CD. That sample had high growth of both mesophiles and yeast, so the mold could have been outcompeted by those. As (Hell et al. 2009) reports, molds that produce mycotoxins could be a problem in dried products. The mold analyzes in this experiment was not specific to which strains of mold growing in the samples, so it is not sure toxin producing molds was present. It could be interesting to perform more

analyses of the molds, to reveal which strains that was growing, and if that could be a problem regarding food safety.

5.8 SENSORY EVALUATION OF DRIED TOMATO BOATS

To better understand how the consumers react to the dried products, sensory evaluations could have been performed. The problem with the dried vegetables was that they usually are used in cooked meals, together with other ingredients. Just presenting the consumers the dried or rehydrated samples would not have given the participants a real picture of how the vegetables would taste and feel like in the way the products was meant to be used. Making different meals with the dried products used in the right way would have been necessary. During this work, it was not time for this.

Anyway, the dried fruits produced in another part of the project were presented for a focus group consisting of food science and economy students from SUA, Morogoro. When the survey of the dried fruits was done, samples of dried tomatoes in oil were presented. The tasting of the tomatoes was not a serious sensory evaluation, but more a presentation of a new product, and a discussion around it. The tomato boats from the TD was mixed with cooing oil, garlic and spices, and stored for a day. The students had never tasted solar dried tomatoes in oil before, so the product was new for everyone. All of the students liked the appearance and smell of the product. They did not like the taste of it, except from one of the girls. The participants said that if the taste was as good as the smell, they would have bought and used the products in stews or together with meat.

Considering the positive responses about the tomatoes in oil, it could be interesting to see if other varieties of tomatoes could give a better taste to the product, and maybe it could have been a marked for a product like that.

5.9 CHALLENGES DURING THE EXPERIMENT PERIOD

Before leaving for Tanzania, there was not much information of what to actually be done, except solar drying of vegetables. If more information had been provided, better planning of the different experiments could have been worked out.

Working in Tanzania was very different from what one could expect after working in Norway. Before the work of this study was started, more analyzes than those actually performed was planned. A mechanical gas/electricity dryer was bought for the project and placed in the production building, but lack of electricity made the use of this not possible. Lack of clean tap water, electricity which was away almost daily in the end of the project, and laboratory equipment that after Norwegian standards was not always working as supposed was some of the challenges that was a part of the daily working life. The fact that it could take long time to get equipment needed for further work also slowed down the process.

One of the plans was to perform microbiological tests of the samples several times during the stay, to see how the growth developed over time. That came out as difficult caused by low capacity of the sterilizing equipment, and as discovered later, not adequate sterilization of the equipment. Because of this, the contaminated water, and the fresh samples was not tested, and the study of change of growth over time was not completed.

The L-ascorbic acid detection performed in Tanzania did not go as planned, so the raw products were not analyzed. The mineral analyzes could also been more precise with better laboratory routines.

The TD to be used during the production of the dried samples was not built when the work in Tanzania started. The ideal way of producing the dried products to be tested would have been to dry the same vegetables in the two driers the same day, so the weather conditions was the same during the drying period.

If the experiments were better planned, the temperature and RH inside the driers during the drying period could have been measured. Through studies of the two factors compared to the MC of the samples, it could maybe be possible to design a table of how long drying time which is needed for specific temperature and humidity conditions during the drying process. During our work, the decision of which the products were dry enough was decided just by looking at and touching the products.

6 CONCLUSION

The MC of the dried samples from the TD was lower than what measured in the products dried in the CD, probably because the higher temperature and AV in the TD. None of the samples was as dry as (Sharma et al. 2009) presents as safe values regarding degradation of the product quality, but most of the samples would probably have a prolonged shelf life even if the MC was not as low as suggested. Further storage experiments are needed to confirm that.

Tomatoes were the products that gave most challenges regarding the drying process. Some samples from the CD did not dry quickly enough and visible growth of mold was detected. There was also visible growth of mold on both tomato boats and slices in the TD, and the problem in this case could have been unstable weather conditions with high RH.

The weather caused some problems during the drying in the TD, and that showed that the process was best suited for the stable dry and sunny season.

Regarding the nutrients of the dried products, L-AA degradation was higher in samples dried in the TD compared to those dried in the CD. The results from the tomatoes showed that bigger pieces of material to be dried, was less degraded during the drying process. Finding a product size as big as possible, but still small enough to dry properly could be of interest considering the nutritional value of the products. The problems during preparation of samples for the mineral analyses led to high standard deviations between the parallels of the tested samples. It was therefore difficult to come with a reliable conclusion about the results. Anyway the mineral content of the dried samples seemed to be higher than what presented in food composition tables from Tanzania and Norway, for some of the minerals and samples, and lower in others. Overall the dried products could contribute positive to the daily intake of the minerals usually found in the tested vegetables on the same level as the fresh products. The protein content of the vegetables is generally low, but the products dried in this study had an adequate content compared to what one could expect.

When it comes to the rehydration properties of the dried carrots, it was clear that carrots without sugar pretreatment had the highest rehydration rate and the sample with highest degree of pretreatment had the lowest. After boiling the samples for 30 minutes, which is what usually done when preparing the meals where dried vegetables are used, this different in

RR would probably not give any noticeable difference for the consumer. The appearance of the products was less wrinkled in the samples with high degree of sugar treatment, and that could be positive for consumer acceptance.

The microbiological studies of the dried vegetables showed that the samples from the TD had a significant lower number of microorganisms present in the products. Samples with lower MC also had significant lower growth, but the samples from the TD was generally more dry than those from the CD, so there is probably a relation between those two factors. Some of the samples contained coliform bacteria, and that indicates that the hygiene performed during production and packaging was not good enough. There was growth of fungi in all of the samples, and that could lead to production of mycotoxins in the dried products. In the onion samples where one was frozen after packaging and the other not, there was less growth in the sample that was frozen, but in the tomatoes the not frozen sample had less growth. The testing material was not enough to really say if freezing the sample should be done or not, so further analyses should be performed to get a better picture of the procedure of freezing the samples after drying. A second drying after freezing and before packaging could be considered to remove the excess moisture from the product surfaces. When it comes to the carrots pretreated with sugar solution, there was not any clear tendency of more or less growth in samples pretreated or not.

The main targets of this work were to study different production methods to find a suitable way of drying vegetables in rural areas of Tanzania, including use of two different dryers, pretreatment of the carrot samples, and slicing size for tomatoes. Difference in the nutritional composition of the products dried by the two driers, and the microbiological quality was also studied.

When comparing the total factors studied in this work, it is clear that both the CD and the TD had their advantages. The CD had a slower drying time and the MC did not get as low as in the samples from the TD. The microbiological activity was higher in the samples from the CD. The positive result regarding the CD was the higher retention of L-AA. The mineral and protein content was adequate in samples from both the dryers. The appearance and rehydration properties were better in samples from the TD, and that could be positive when presenting the products for the consumers. Overall the TD may have some more advantages compared to the CD, but when thinking about the higher costs for buying the TD, more

advanced equipment to maintain and more need of space, the CD seems like the best dryer for rural areas.

Regarding the quality of the dried products, a standard for how dry the product should be and how to decide when this MC is reached needs to be developed.

7 REFERENCES

Adams, M. R. & Moss, M. O. (2000). *Food Microbiology*. 2 ed. Cambridge, Uk: The Royal Society of Chemistery.

Aktas, T., Fujii, S., Kawano, Y. & Yamamoto, S. (2007). Effects of pretreatment of sliced vegetables with trehalose on drying characteristics and quality of dried products. *IChemE*, 85 (Trans IChemE, Part C, September 2007): 178-183.

Askerud, H. & Kristoffersen, E. (2007). *Arbeidsbeskrivelse Kjeldahl-N, IHA-nr.:1040*. In Institute for Animal and Aquacultural Sciences, T. N. U. o. L. S. (ed.).

. Ås, Norway. Available at: http://www.umb.no/statisk/iha/labtek/arb_kj_n.pdf.

Bechoff, A., Dufour, D., Dhuique-Mayer, C., Marouzé, C., Reynes, M. & Westby, A. (2009). Effect of hot air, solar and sun drying treatments on provitamin A retention in orange-fleshed sweetpotato. *Journal of Food Engineering*, 92 (2): 164-171.

Damodaran, S., Parkin, K. L. & Fennema, O. R. (2008). *Fennema's Food Chemistry*. 4 ed. Boca Raton: Taylor & Francis Group.

Dashman, T., Blocker, D. E. & Baker, N. (1996). *Laboratory Manual for Human Nutrition*. 2 ed. Amsterdam, Netherlands: Harwood academic publishers.

Fellows, P. J. (2000). *Food processing technology, Principles and practice*. 2 ed. Cambrige, England: Woodhead Publishing Limited.

Gallali, Y. M., Abujnah, Y. S. & Bannani, F. K. (2000). Preservation of fruits and vegetables using solar drier; a comparative study of natural and solar drying, III; chemical analyses and sensory evaluation data of the dried samples (grapes, figs, tomatoes and onions). *Renewable Energy*, 19: 203-212.

Gornicki, K. & Kaleta, A. (2007). Drying curve modelling of blanched carrot cubes under natural convection condition. *Journal of Food Engineering*, 82 (2): 160-170.

Grønt, O. f. F. o. (2011). *Leksikon, Grønnsaker*. In grønt, O. f. f. o. (ed.). Oslo, Norway. Available at: http://www.frukt.no/leksikon/gronnsaker/.

Hell, K., Gnonlonfin, B. G. J., Kodjogbe, G., Lamboni, Y. & Abdourhamane, I. K. (2009). Mycoflora and occurrence of aflatoxin in dried vegetables in Benin, Mali and Togo, West Africa. *International Journal of Food Microbiology*, 135 (2): 99-104.

Hossain, M. & Bala, B. (2007). Drying of hot chilli using solar tunnel drier. *Solar Energy*, 81 (1): 85-92.

Lin, T. M., Durance, T. D. & Scaman, C. H. (1998). Characterization of vacuum microwave, air and freeze dried carrot slices. *Elsevier*, 31 (2): 111-117.

Lukmanji, Z., Hertzmark, E., Mlingi, N., Assey, V., Ndossi, G. & Fawzi, W. (2008). Tanzania Food Composition Tables.

Løvås, G. G. (2004). *Statistikk for universiteter og høgskoler*. 2 ed. Oslo, Norway: Universitetsforlaget AS.

Mattilsynet, Helsedirektoratet & Oslo., U. i. (2006). *Matvaretabellen* In Mattilsynet, H. o. U. i. O. (ed.). Informasjon om næringsstoffer i maten. Oslo. Available at: www.matportalen.no/matvaretabellen.

Mazengo, M. C., Simell, O., Lukmanji, Z., Shirima, R. & Karvetti, R.-L. (1997). Food consumption in rural and urban Tanzania. *Acta Tropicana* (68): 313-326.

McClements, J. (2011). *Analysis of Ash and Minerals*. Massachusetts, USA: Department of Food Science, University of Massachusetts Amherst, MA Available at: http://people.umass.edu/~mcclemen/581Ash&Minerals.html.

Misra, N. (1981). Influence of Temperature and Relative Humidity on Fungal Flora of some Spices in Storage. *Z eitschrift für Lebensmittel-Untersuchung und-Forschung* (172): 30-31.

Mongi, R. (2010). Temperature and Humidity Data (November. 2010).

Ndawula, J., Kabasa, J. D. & Byaruhanga, Y. B. (2004). Alterations in fruit and vegetable β-carotene and vitamin C content caused by open sun drying, viqueen covered and polyethyl. *African Health Sciences* 4(2).

Nes, M., Müller, H. & Pedersen, J. I. (2004). *Ernæringslære*. 5 ed. Oslo, Norway: Landsforeningen for kosthold og Helse.
Norwegian recommendations for nutrition and physical activity. (2005). IS-1219. Oslo: Norwegian Directorate of Health.
Pangavhane, D. R. & Sawhney, R. L. (2002). Review of research and development work on solar dryers for grape drying. *Energy Conversion and Management* (43): 45-61.
Rastogi, N. (2004). Influence of osmotic pre-treatments on rehydration characteristics of carrots. *Journal of Food Engineering*, 65 (2): 287-292.
Sharma, A., Chen, C. R. & Vu Lan, N. (2009). Solar-energy drying systems: A review. *Renewable and Sustainable Energy Reviews*, 13 (6-7): 1185-1210.
Singh, B., Panesar, P. S., Nanda, V. & Kennedy, J. F. (2010). Optimisation of osmotic dehydration process of carrot cubes in mixtures of sucrose and sodium chloride solutions. *Food Chemistry*, 123 (3): 590-600.
SIU. (2011). *Empowering Women to Participate in the Higher Level of Fruit and Vegetables Value Chain Through Production of Dried Products*. In (SIU), T. N. C. f. I. C. i. H. E. (ed.). Development cooperation, SIU Project database, NUFU Women's Rights and Gender Equality. Bergen, Norway. Available at: http://espresso.siu.no/projects/?wicket:interface=:2:1.
Tanzania Food and Nutrition Centre. (2011). In Welfare, M. o. H. a. S. (ed.). Dar es Salaam, Tanzania. Available at: http://www.tfnc.or.tz/index.htm.
Tindall, H. D. (1983). *Vegetables in the Tropics*. 1 ed. London, UK: The Macmillan Press LTD.
Togrul, I. T. & Pehlivan, D. (2002). Mathematical modelling of solar drying of apricots in thin layers. *Journal of Food Engeneering* (55): 209-216.
Torreggiani, D. (1993). Osmotic dehydration in fruit and vegetable processing. *Food Research International* (26): 59-68.
Tortora, G. J., Funke, B. R. & Case, C. L. (2007). *Microbiology an introduction*. 9 ed. San Francisco, CA: Pearson Education, Inc.
UNA. (2011). *Globalis.no*: The United Nations Association of Norway UNA. Available at: http://www.globalis.no/Land/Tanzania/(show)/indicators.
USDA. (2010). *USDA National Nutrient Database for Standard Reference*. 23 ed. In U.S. Department of Agriculture, A. R. S. (ed.). National Nutrient Database. Available at: http://www.nal.usda.gov/fnic/foodcomp/search/.
Warriss, P. D. (2000). *Meat Science: An Introductory Text*. Oxon, UK: CABI Publishing.
Wills, R., McGlasson, B., Graham, D. & Joyce, D. (2007). *Post Harvest, An introduction to the physiology and handling of fruit, vegetables and ornamentals.* 5 ed. Oxfordshire, UK: CAB International.
Wold, A.-B. (2004). *Antioxidant activity in tomato (Lycopersicon esculentum Mill.) and cabbage (Brassica oleracea L.), and the content of individual glucosinolates in cabbage, Effects of maturity, fertilisation and storage conditions*. Ås: Agricultural University of Norway, Department of Plant and Environmental Sciences.
Zinedine, A., Brera, C., Elakhdari, S., Catano, C., Debegnach, F., Angelini, S., Desantis, B., Faid, M., Benlemlih, M. & Minardi, V. (2006). Natural occurrence of mycotoxins in cereals and spices commercialized in Morocco. *Food Control*, 17 (11): 868-874.

8 APPENDIX

Appendix 1: Synopsis of the NUFUGe-2008/10181 project.

Appendix 2: Description of all the samples produced.

Appendix 3: Results from Minitab.

Appendix 4: Pictures from the drying area in Morogoro.

Appendix 1

Empowering Women to Participate in the Higher Level of Fruit and Vegetables Value Chain Through Production of Dried Products

Empowering Women to Participate in the Higher Level of Fruit and Vegetables Value Chain Through Production of Dried Products

Hovedpartnere

Norwegian University of Life Sciences (NO-UMB)

Kontaktperson(er): Wicklund, Trude (trude.wicklund@umb.no)

Sokoine University of Agriculture (TZ-SUA)

Kontaktperson(er): Гemu, Anna (aatemu@suanet.ac.tz)

Synopsis/beskrivelse

In Tanzania women are the major participants in the agricultural sector and thus the economy in general. However, women do not extract equitable value from the agricultural marketing chain due to barriers that make them only participate in the lower nodes in the marketing chain that is production and marketing of fresh products with limited value addition. These barriers include the lack of access to technologies that add value to the product before it is marketed to the final consumer, such as lack of knowhow, inability to meet quality requirements and lack of capacity to organize the chain. Whereas women are the major food processors at household level for home consumption, they are not major processors of food for commercial markets. Much of fruits and vegetables produced by women are lost during transportation and storage due to inadequate processing and preservation leading to low economic returns to their labour. Improving and enhancing their skills and knowledge about the processing technologies, unearthing information about nutrition of processed fruits and vegetables, developing products that can be produced by women, setting quality controls and ensuring product registration, earmarking markets for new products will assist women in entering to higher nodes. It is certain that gender equality and empowerment of women cannot come about without first empowering them economically. Most women in Tanzania are less empowered due to lack of knowledge, skills and information, and lack of business ideas due to low education and limited exposure. This project will provide the knowledge, skill, business ideas and oversee the use and development of the research information while gauging the extent of the barriers that hinder women from participating in value addition to agricultural products.

Poor knowledge of preservation and processing of fruits and vegetables, reduce their shelf life. Such deterioration contributes largely to economic losses incurred by women in the chain who participate as producers, traders, and consumers.
New methods of processing food, combined with imaginative marketing, add value to foodstuffs by making them available for longer period, without loss of nutritive value. Food quality and safety are of increasing concern to consumers and are critical for gaining access to high value markets in the domestic and international value chains. Specifically, this is more so for high value products such as fruits and vegetables. The need to provide assurance of quality and safety along the agro-food supply chain is driving the integration of food chains and the long-term relationships between the different

farmers, traders and processors. Solar dryers can effectively be used to produce good quality dried fruits and vegetable products. There are several types of solar dryers in the market. They vary in their effectiveness by construction and climatic conditions. Thus, this requires a processor to make choices of appropriate technology for specific location. Appropriate solar dryer is one that can dry product rapidly, consistently and is more effective at preserving the nutritional quality of foods compared to traditional sun drying. For some reasons Tanzania is far from tapping the potential of solar drying technologies. But this could be partly due to lack of scientific research information or lack of business skills of potential investors.

The proposed research will fill the information gap, provide demonstration, and promote appropriate technology to appropriate beneficiaries (mainly women) and also develop market for dried fruits and vegetables. The project will also facilitate formalization of marketing chain of fruits and vegetables through information provisioning to assist development of women enterprises. The project will strengthen capacity of Sokoine University of Agriculture through support in training of one female staff at PhD level in agricultural economics. It will also support two female students in their Msc research and thesis writing.

Appendix 2:

Sample	Storing conditions	Drying time (hours)	Abbrevations
Carrots, no sugar, cabinet	Not frozen	52	Carrot, CD, 0, NF
Carrots, 10 % sugar, 10 min, cabinet	Not frozen	52	Carrot, CD, 10/10, NF
Carrots, 10 % sugar, 20 min, cabinet	Not frozen	52	Carrot, CD, 10/20, NF
Carrots, 20 % sugar, 10 min, cabinet	Not frozen	52	Carrot, CD, 20/10, NF
Carrots, 20 % sugar, 20 min, cabinet	Not frozen	52	Carrot, CD, 20/20, NF
Carrots, no sugar, cabinet	Frozen	52	Carrot, CD, 0, F
Carrots, 10 % sugar, 10 min, cabinet	Frozen	52	Carrot, CD, 10/10, F
Carrots, 10 % sugar, 20 min, cabinet	Frozen	52	Carrot, CD, 0/20, F
Carrots, 20 % sugar, 10 min, cabinet	Frozen	52	Carrot, CD, 20/10, F
Carrots, 20 % sugar, 20 min, cabinet	Frozen	52	Carrot, CD, 20/20, F
Carrots, no sugar, tunnel	Not frozen	52	Carrot, TD, 0, NF
Carrots, 10 % sugar, 10 min, tunnel	Not frozen	52	Carrot, TD, 10/10, NF
Carrots, 10 % sugar, 20 min, tunnel	Not frozen	52	Carrot, TD, 10/20, NF
Carrots, 20 % sugar, 10 min, tunnel	Not frozen	52	Carrot, TD, 20/10, NF
Carrots, 20 % sugar, 20 min, tunnel	Not frozen	52	Carrot, TD, 20/20, NF
Carrots, no sugar, tunnel	Frozen	52	Carrot, TD, 0, F
Carrots, 10 % sugar, 10 min, tunnel	Frozen	52	Carrot, TD, 10/10, F
Carrots, 10 % sugar, 20 min, tunnel	Frozen	52	Carrot, TD, 10/20, F
Carrots, 20 % sugar, 10 min, tunnel	Frozen	52	Carrot, TD, 20/10, F
Carrots, 20 % sugar, 20 min, tunnel	Frozen	52	Carrot, TD, 20/20, F
Contaminated Carrots, cabinet	Not frozen	52	Con Carrot, CD, NF
Contaminated Carrots, cabinet	Frozen	52	Con Carrot, CD, F
Tomato slices, cabinet	Not frozen	52	Tomato S, CD, NF
Tomato lobes, cabinet	Not frozen	76	Tomato L, CD, NF
Tomato slices, cabinet	Frozen	52	Tomato S, CD, F
Tomato lobes, cabinet	Frozen	76	Tomato L, CD, F
Tomatoe slices, tunnel	Frozen	52	Tomato S, TD, F
Tomato lobes, tunnel	Frozen	52	Tomato L, TD, F
Onion, cabinet	Frozen	52	Onion, CD, F
Onion tunnel	Not frozen	52	Onion, TD, NF
Onion tunnel	Frozen	52	Onion, TD, F

Appendix 3:

Copys from Minitab:

Moisture content:

Correlations: Dryer; Moisture content

Pearson correlation of Dryer and Moisture content = -0,953
P-Value = 0,000

L-Ascorbic acid:

Correlations: Dryer; L-ascorbic acid

Pearson correlation of Dryer and L-ascorbic acid = -0,351
P-Value = 0,440

When carrot samples not was included:

Correlations: Dryer; L-ascorbic acid

Pearson correlation of Dryer and L-ascorbic acid = -0,644
P-Value = 0,241

Correlations: Dryer; L-ascorbic acid in onions

Pearson correlation of Dryer and L-ascorbic acid in onions = -1,000
P-Value = *

Correlations: Dryer; L-ascorbic acid in tomatoes

Pearson correlation of Dryer and L-ascorbic acid in tomatoes = -0,994
P-Value = 0,071

Microbiology:

Correlations: Dryer ; Log

Pearson correlation of Dryer x and Log = -0,695

P-Value = 0,000

Correlations: Dryer ; Log PCA

Pearson correlation of Dryer xx and Log PCA = -0,725

P-Value = 0,001

Correlations: Dryer ; Log RB

Pearson correlation of Dryer xxx and Log RB = -0,743

P-Value = 0,001

Correlations: Log number; Pretreatment

Pearson correlation of Log number and Pretreatment = -0,087
P-Value = 0,629

Pearson correlation of Cutting and Log number = -0,018
P-Value = 0,948

Correlations: Drier; Log number

Pearson correlation of Drier and Log number = -0,220
P-Value = 0,569

Correlations: Moisture content; Log number

Pearson correlation of Moisture content and Log number = 0,685
P-Value = 0,000

Appendix 4:

Picture 1: Blanching of carrots.

Picture 2: Drying onions in the cabinet dryer.

Picture 3: The slicing equipment.

Picture 4: Fresh and dried tomatoes.

Picture 5: Fresh and dried carrots.

Picture 6: Production clothes.

Picture 7: Sterilization kettles.

Picture 8: The tomatoes in oil presented for the consumers.

Picture 9: Working at the tunnel drier.