# Solar Drying of Tropical Fruits

## Soltørking av tropiske frukter

Siv Berit Lundberg

Norwegian University of Life Sciences
Department of Chemistry, Biotechnology and Food Science
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# Preface

This assignment is written as a finishing master thesis at the Norwegian University of Life science (UMB), Department of Chemistry, Biotechnology and Food Science (IKBM) the spring 2011. The work has been in cooperation with the Tanzanian Sokoine University of Agriculture (SUA), Department of Food Science and Technology.

I wish to thank Kathrine Strøm for good teamwork during the drying and the analyses, and a great stay in Tanzania. The trip would not have been the same without you. My thanks also go to my two supervisors Associate Professor Trude Wicklund at UMB and Dr. Bernadette Ndabikunze at SUA for good guidance during the work.

I want to thank Raymond Jofrey for help with everything during the work in Tanzania and everyone who helped with the drying, the lab work and the sensory evaluations in Tanzania. I also wish to thank all the people who participated in making the trip to Tanzania to a good and memorable journey.

I wish to thank the Norwegian lab technicians for good help at the lab, and everybody who participated in the focus group interview and in the consumer tests.

In the end my thanks goes to mom, dad, Anette, friends and fellow students who have made my student time to a nice period.

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# Abstract

The aim of this master thesis was to dry fruits using two types of solar driers and to study changes in composition of the fruits during the process. The drying and parts of the analyses were performed in Tanzania; whereas the finishing analyses were performed in Norway.

Mango, pineapple and banana were cut in pieces and dried in cabinet dryers with natural convection and a tunnel dryer with forced convection. Banana and pineapple from the tunnel dryer did not get the desired quality due to bad weather conditions.

The dried fruit was stored at -18 °C in a freezer, whereas parts of some of the batches were stored at room temperature for microbiological control. Microbiological analyses were conducted in both Tanzania and Norway with varying results. The microbiological analyses from Norway showed that the samples contained some microorganisms, but the numbers were not too high. Samples stored in the freezer had higher levels of microorganisms than the samples stored at room temperature.

The content of vitamin C was analyzes by HPLC. The result showed that longer drying time resulted in lower content of vitamin C. There were also differences between the fruit types, with mango containing most vitamin C. Fruit samples were analyzed for protein and mineral content, but these analyses gave dubious results. The contents should not change during the drying process, and the samples should contain the same amount of protein and minerals in dry matter; however this was not the case. A control protein analysis for one of the samples gave much lower result than the original analysis.

A focus group study was conducted in Tanzania and a consumer test was conducted in both Tanzania and Norway. Seven samples were chosen for the consumer test based on the results from the focus group. The result from the sensory evaluation implied that Tanzanian consumers liked the product better than Norwegian consumers, and that they were more interested in buying them. The Norwegian consumers differentiated more between the products and were interested in buying some of them.

The studies showed that under equal conditions, the drying was best in the tunnel dried, the vitamin C content was best preserved in products with highest moisture content, and the consumers preferred the mango and pineapple samples. Further studies should be carried out to strengthen these claims.

# Sammendrag

Hensikten med denne masteroppgaven var å tørke frukt i to typer soltørkere og å undersøke forandringer i frukten under tørkeprosessen. Tørkingen og deler av analysene ble utført i Tanzania i perioden 16. januar til 16. mars 2011, mens resten av analysene ble utført i Norge.

Mango, ananas og banan ble delt opp i biter og tørket i kabinerttørkere med naturlig konveksjon og tunneltørke med tvunget konveksjon. Dårlig værforhold under deler av tørkingen førte til at ananas og banan fra tunelltørken ikke fikk den ønskede kvaliteten.

Den tørkede frukten ble lagret i en fryser ved -18 °C, deler av noen av partiene ble også lagret ved romtemperatur for mikrobiologisk kontroll. Mikrobiologiske undersøkelser ble utført både i Tanzania og Norge med noe varierende resultater. De mikrobiologiske undersøkelsene fra Norge viste at prøvene inneholdt noe bakterier, sopp og gjær, men at mengdene ikke var altfor høye. Prøvene lagret i fryser hadde høyere innhold av mikroorganismer enn prøvene lagret i romtemperatur.

Innholdet av C vitamin ble analysert ved hjelp av HPLC. Resultatet viste at lenger tørketid gav lavere innhold. Det var også forskjell mellom frukttypene, mango inneholdt mest C vitamin. Fruktprøvene ble analysert for protein og mineral innhold, men disse analysene fikk et noe tvilsomt resultat. Innholdet burde ikke endret seg under tørkeprosessen, og prøvene burde hatt samme mengde protein og mineraler i tørrstoff. Dette var ikke tilfelle. Det ble utført en kontroll protein analyse for en av prøvene, denne gav et mye lavere resultat enn den opprinnelige analysen.

Det ble utført en fokusgruppe undersøkelse i Tanzania og en forbrukerundersøkelse blant tanzanianske og norske forbrukere. Syv prøver ble på grunnlag av fokusgruppen valgt ut til forbrukerundersøkelsen. Resultatet viste at tanzanianske forbrukerne likte produktene bedre enn norske forbrukerne, og at de var mer interessert a å kjøpe dem. De norske forbrukerne skilte mer mellom produktene og var interessert i å kjøpe noen av dem.

Undersøkelsene viste at under like værforhold var det best tørking i tunelltørka, at vitamin C innholdet ble best bevart i produktene med høyest vanninnhold, og at forbrukerne foretrakk mango og ananas. Videre undersøkelser bør gjøres for å styrke disse påstandene.

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# 1. Introduction

In the world, many organisations promote cooperation between different countries and continents regarding research and education. The Norwegian Centre for International Cooperation in Higher Education (SIU) is a public Norwegian agency with this purpose. One part of their work is cooperation with developing countries and this is an important part of the Norwegian aid work. The Norwegian Programme for Development, Research and Education (NUFU) is a program for academic cooperation; it includes researchers and institutions in developing countries and their partners in Norway. The program focuses on research, education, capacity building and institutional development. The goal is to support higher education in developing countries related to national development and poverty reduction, and promote academic cooperation in the South and between South and North (SIU 2011).

The project "Empowering Women to participate in the Higher Level of Fruit and Vegetables Value Chain through Production of Dried Products" (project number NUFUGe-2008/10181) is a part of the NUFU Women's Rights and Gender Equality program. The aim of the project is to teach women processing of fruits and vegetables by drying them in solar dryers. This will increase the value of the product extend the shelf life. The project is a collaboration project between TZ-Sokoine University of Agriculture (SUA) in Morogoro, Tanzania and NO-Norwegian University of Life Science (UMB) in Ås, Norway (NUFU 2009).

The diet is an important factor for the human well-being. Wrong diet can lead to diseases; lack of certain nutrients can lead to deficiencies. Too little food can lead to under-nutrition, and too much food with high energy content can lead to over-nutrition and result in obesity, diabetes type II and cardiovascular diseases. Under-nutrition is most common in developing countries, whereas over-nutrition is most common in industrialized countries, but is also found in developing countries (WHO 2003). Tanzania is one of the countries struggling with both under- and over-nutrition; under-nutrition in the form of protein-energy malnutrition and micronutrients deficiency and over-nutrition in the form of obesity, diabetes and hypertension. Approximately one fourth of Tanzanian children under 5 years are underweight for their age and 60 % are anaemic. At the same time the prevalence of diabetes and hypertension are increasing (Lukmanji et al. 2008). To prevent both over- and under-nutrition a good diet is important. Dried fruit could be included in such diets. It can be used as a healthy snack to prevent over-weight, or as a source of nutrients to prevent deficiencies.

Drying leads to physical and chemical changes in the fruit. The physical changes may be changes in size, shape, colour and texture, whereas the chemical changes are often nutritional

changes. Some of these changes may lead to lower quality and nutrient loss (Augustus Leon et al. 2002). It is therefore important to give the fruit the right conditions during the drying to maintain good nutrition value, and to obtain good quality of the products.

## 1.2 Research question

This master thesis is a part of the NUFU project. The aim was to dry fruits using different types of solar driers and to study changes in composition of the fruits during this process. The task started with many ideas about what to study, but not all of them were possible to conduct. Sugar and acid-profile, vitamin A and fibre content were some of the studies which were discarded. It was intended to use an electrical dryer, but unfortunately problems with power supply prevented this.

The following targets were studied

- **Different drying time of the products**
- **Drying in two different dryers, a cabinet dryer and a tunnel dryer**
- **Microbiological control of the dried products**
- **Investigate some nutritional components of the dried material, compared to fresh products**
- **Consumer preferences for the product among Norwegian and Tanzanian consumers**

# 2. Theory

## 2.1 The NUFU project

The aim of the NUFU project is to teach women how to process fruits and vegetables by using solar dryers. Women in Tanzania are major participants in production and marketing of fresh products, however this does not add much value to the products. By teaching the women to process fruits and vegetables by drying them, they can increase both value and shelf life of the products. Solar drying is a relatively slow process and is assumed to be done between other duties (NUFU 2009).

According to the project description the objectives with the project are:

- *To identify an appropriate improved drying technology.*
- *To develop consumer-acceptable and good quality dried fruits and vegetables products with high potential for commercialisation.*
- *To develop an effective value chain for dry fruits and vegetables.*
- *To promote the adoption of post-harvest technologies for better quality raw materials for fruit and vegetable drying.*
- *To develop women's enterprise development conceptual framework that can be applied in elsewhere for economic empowerment of various groups in a community.(NUFU 2009)*

The project synopsis can be found in Appendix 1.

## 2.2 Drying

Drying can be done in many different ways; some methods are quite complicated and require a lot of equipment and energy, hence a lot of money. Others are simpler, require less equipment and electric energy, and are therefore cheaper. Which drying method one should use depends on the product to be dried, which purpose the drying has, and which resources available (Belessiotis & Delyannis 2009).

Drying, using energy from the sun has been used for food preservation since ancient times. It has been used to preserve vegetables, fruits, fish and meat. In the beginning they used open sun drying; the technique developed and they started to use drying installations which gave more air circulation and better drying. In later days many new ways of preserving food, as canning and freezing, have been invented but sun and solar drying are still used for small amounts (Belessiotis & Delyannis 2009).

Open sun drying is when the product to be dried is exposed directly to the sun. The product is cut into pieces and laid out in the sun, without anything to cover it. The sun's rays heats it directly and the natural circulation of air removes the moisture (Belessiotis & Delyannis 2009). This method has many disadvantages. The product can be spoiled by rain, wind, moisture and dust. It can also be destroyed of decomposition, insect attacks and fungi and it is exposed to birds and animals. Open sun drying requires a large area, it is time consuming, does not meet the international quality standards and cannot be sold on the international market (Sharma et al. 2008).

Mechanical drying is drying using equipment that requires fuel or electricity to dry the products. The incoming air is heated with boilers, and fans force the air through the drying area. This method is faster than sun drying, it requires less space and gives the product better quality (Sharma et al. 2008).

Solar drying is drying using the sun energy, but excludes open air sun drying. The driers have different designs, but they are all more effective than sun dryers and have lower operating costs than mechanical dryers (Sharma et al. 2008).

In the article "Solar-energy drying systems: A review", Sharma et al. (2008) lists some reasons why solar dryers improve the traditional open-air sun drying:

- *It is faster*. The cabinet captures the air and heats it; this gives a higher temperature and a faster drying. It makes is possible to enlarge the solar collection area and collect more of the sun's energy.
- *It is more efficient.* The products are in closed rooms, hence destructive animal and insects cannot access the products. The postharvest losses will be smaller as the drying is faster.
- *It is hygienic.* The drying takes place in controlled environment; this reduces the chance for contamination from the environment.
- *It is healthier.* Shorter drying time gives less treatment of the products and more of the nutrients will remain in the products.

Drying the product will increase the shelf life, but it is important to dry it the right way. The moisture content must be below a certain level, and it cannot be too much microorganisms present. Different products have different composition and different content of sugar, the maximum moisture content is therefore different (Sharma et al. 2008).

## 2.3 Solar Drying

### 2.3.1 The technics

The way of classifying the technic of solar drying is direct and indirect solar drying.

#### *2.3.1.1 Direct solar drying*

In direct solar drying the product to be dried is placed in a cabinet covered with plastic or glass. Some of the sun's rays will penetrate this cover, while others will reflect to the atmosphere, like shoved in figure 2.1. The temperature inside the cabinet will rise from this radiation, and the product to be dried will lose moisture (Sharma et al. 2008).

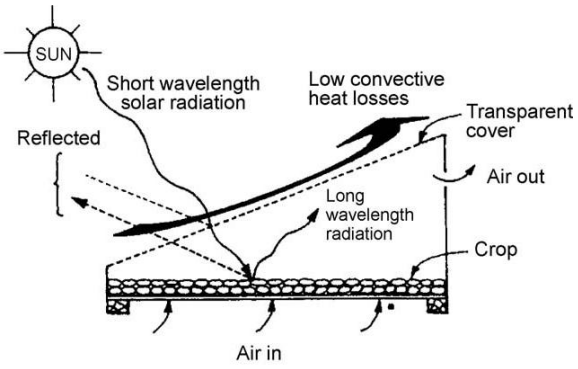



**Figure 2. 1 Principles of direct solar drying. Figure from (Sharma et al. 2008)**

#### *2.3.1.2 Indirect solar drying*

In indirect solar drying, the product is also placed in a cabinet, but it is not exposed to direct radiation, as a collector or a reflector is used. A reflector reflects the air and it enters the cabinet from below, like showed in figure 2.2. Another way of indirect solar drying is by using a separate unit which takes up air and heats it on its way to the cabinet, like showed in figure 2.3. Indirect solar drying is more gentle on the products as the surface not is exposed directly to the radiation (Sharma et al. 2008).

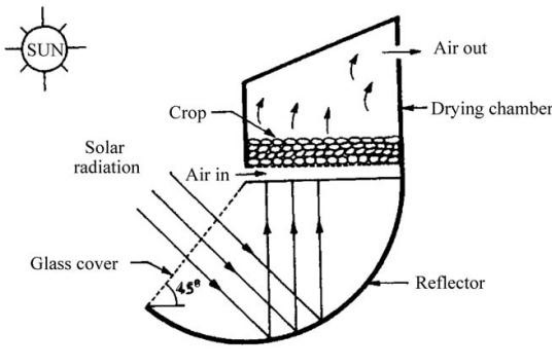



**Figure 2. 2 Principles of indirect solar drying using a reflector. Figure from (Sharma et al. 2008)**

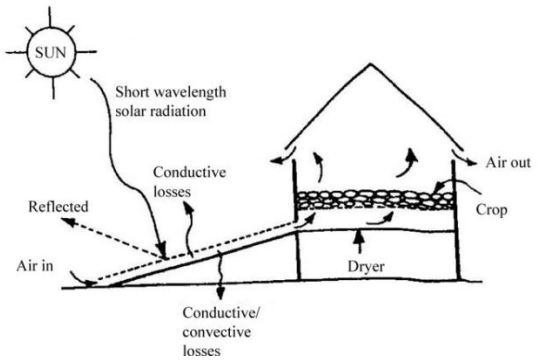



**Figure 2. 3 Principles of indirect solar drying using a collector. Figure from (Sharma et al. 2008)**

### 2.3.2 The dryers

The dryers can be divided into passive and active dryers. One way of classification of solar dryers and drying modes is shown in figure 2.4.

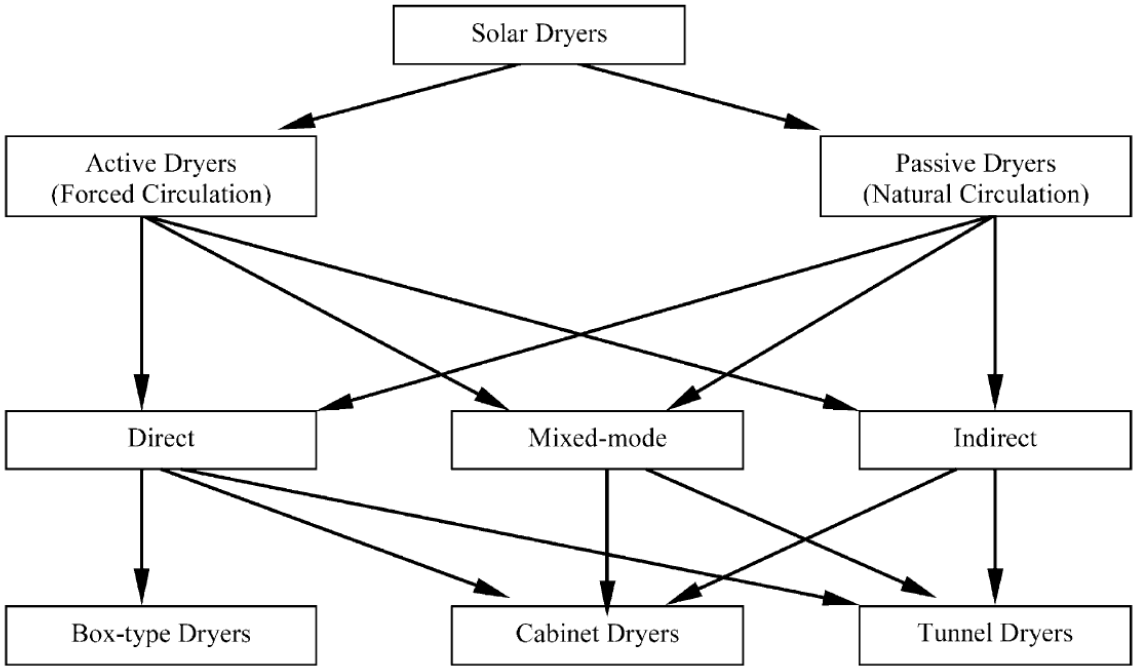



**Figure 2. 4 Classification of solar dryers and drying modes. Figure from (Augustus Leon et al. 2002)**

### *2.3.2.1 Passive dryers - Natural convection*

Passive dryers have only natural air circulation, while active dryers have forced circulation driven by a ventilator. The simplest types of solar dryers are passive dryers with direct radiation. They are cheap, easy to install and operate and require no electricity, but can only have one layer of trays. Cabinet dryers, greenhouse dryers and tent dryers are examples of these. Passive dryers with natural convection are more efficient. They have an air heater, a chimney or both, to heat up the air and get natural circulation. Good circulation makes it possible to have several layers of trays in the drying chamber (Belessiotis & Delyannis 2009).

### *2.3.2.2 Active dryers - Forced convection*

The dryers with natural convection can be good for small amounts of products, but for larger amounts a forced convection solar dryer may be a better option. The air circulation is higher in these dryers, which leads to greater decrease in moisture content and faster drying (Belessiotis & Delyannis 2009).

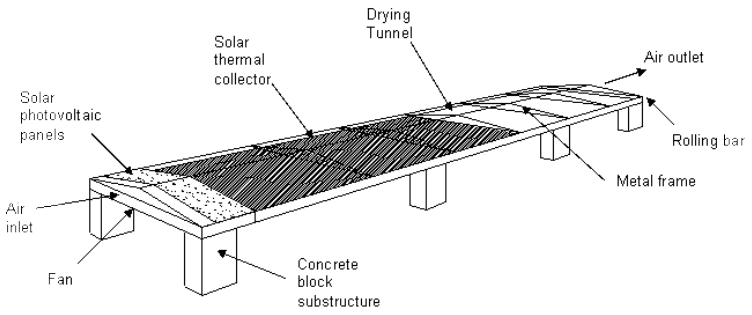



**Figure 2. 5 An overview of a tunnel dryer. Figure from (practicalaction.com 2011)**

There are many types of active dryers, with different systems for air heating and circulation. One type is tunnel dryer as the one in figure 2.5. A tunnel dryer consists of two areas, a heating area and a drying area. The air enters one side of the tunnel, and a fan blows the air through the tunnel. The fan can be operated by a solar module; hence no supply of electricity is needed. The air first enters the heating area, a solar collector. This area has a dark plate which absorbs the sun's rays and heats the air before it is blown to the drying area. In the drying area the crop is dried by the heated air, and the moisture is blown out together with the air (Sharma et al. 2008).

## 2.4 The drying mechanism

The aim of drying is to decrease the moisture content, thereby the water activity. This slows the action of enzymes, bacteria, yeast and moulds and increases the shelf life. Reduction of water in food can be divided in two groups, dehydration and drying. Dehydrated food can maximum contain 2.5 % water, while dried food may contain more than 2.5 % water (Ibarz & Baebosa-Cánovas 2003).

The moisture content in fruit is around 70-90 % and it takes a lot of energy to remove this. To remove the water it is two moisture transfer mechanisms involved,

*1 Migration of moisture from the mass inside to the surface, and*

*2 Transfer of the moisture from the surface to the surrounding air, in the form of water vapour* (Belessiotis & Delyannis 2009).

Van Arsdel and Copley gave in 1963 this explanation about what happed during drying: "*water movement due to capillary forces, diffusion of liquid due to concentration gradients, surface diffusion, water vapour diffusion in pores filled with air, flow due to pressure gradients, and flow due to water vaporization-condensation"(Van Arsdel & Copley 1963).*

The drying process can be expressed in drying rates, where different rates describe different moisture content. The drying rate curve is shown in figure 2.6.

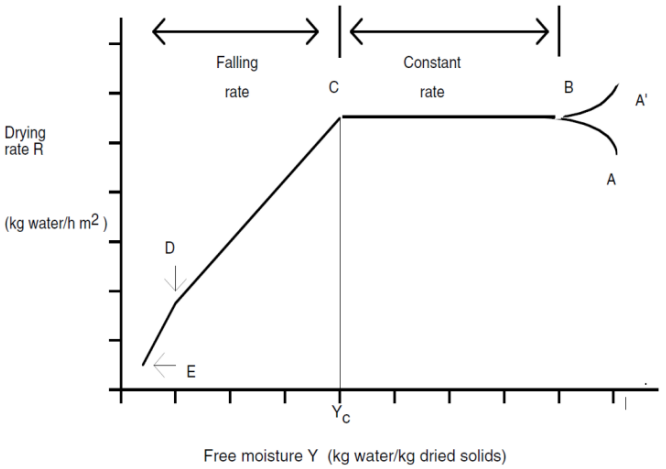



**Figure 2. 6 The drying rate curve. Figure from (Ibarz & Baebosa-Cánovas 2003)**

The rate from B to C is the constant drying rate and is the time when the unbound water is removed. The water behaves as if the solid not is present, the surface is wet, and the water activity is close to one. When the drying reaches point C the drying rate has a decreasing curve. The surface is no longer so wet that it can keep a constant drying rate, the rate is falling. In the first part of the falling rate, from C to D, the wet points of the surface are decreasing, and when it reaches the point D, the surface is completely dry. In the rate from D to E the moisture has to diffuse from the inside to the surface before it evaporate, as such the drying takes longer time (Ibarz & Baebosa-Cánovas 2003).

## 2.5 Fruits

Tanzania produces a lot of agricultural product, most for domestic consumption, but also some for export (FAOSTAT 2011).

### 2.5.1 Mango

Mango is one of the most consumed fruits in the world. The original type, *Mangifera indica*, originates from India. Today, mango is grown in all tropical and subtropical areas. There are many varieties, over 1000. Some are grown all over the world, whereas others are more special for a particular area or country. The varieties differ in size, colour of the peel and fruit flesh, form and taste. Mango is rich in vitamin A and vitamin C (frukt.no 2011c). Mango is a climacteric fruit, which means that it produces ethylene and that the respiration rate increases during ripening. Ethylene can be used in controlled ripening. Ethylene initiates ripening, which means that ethylene can be added to unripe mango and the mango will ripen. 10 µL ethylene /L air will at 29-31 °C ripen unripe mango with a 24 hours treatment time.(Wills et al. 2007)

‘Kaitt’ and ‘Kent’ are two hybrid varieties originating from Florida. ‘Kaitt’ has good eating quality and is disease resistant. The taste is sweet. ‘Kaitt’ is well known and grown all over the world (tropicalfruitnursery.com 2011a). ‘Kent’ is sweet and aromatic, well known and grown all over the world. (tropicalfruitnursery.com 2011b)

‘Dodo’ is a less known variety. It is grown in Tanzania and is a regular variety there. The taste is more acidic then at the hybrid varieties from Florida (personal experience).

### 2.5.2 Pineapple

Pineapple, *Ananas comosus*, is a tropical fruit. It originates from Brazil, but is today grown in all tropical areas. The fruit consist of over 100 separate berries grown together around a stem,

and can be harvested throughout the whole year. The fruit flesh is yellow and juicy and has a fresh and acidic taste. Fresh pineapple contains a lot vitamin A and C (frukt.no 2011a). Pineapple is a non-climacteric fruit, which means that it does not produce ethylene during ripening, and it has a decreasing respiration rate through the maturation rate. This is important to know during storage. If pineapples are stored together with fruits that produce ethylene, this can increase the respiration rate and the quality will decrease faster than under optimal storage conditions (Wills et al. 2007).

### 2.5.3 Banana

Banana, *Musa paradisiaca sapientum*, is the most consumed fruit in the world. It originates from the tropical south-east Asia, but is today grown in the tropical areas of America, Asia and Africa. There are two main varieties of bananas, regular sweet banana and coking banana. These varieties can again be divided in different varieties. 'Kisuuavi' is a kind of mini banana. Mini bananas have a sweeter taste than regular sweet banana, and the fruit flesh is more yellow. Bananas contain more carbohydrates than other fruits, and are a good source for quick energy. They contain fibre, vitamin A, B and E (frukt.no 2011b). Bananas are climacteric fruits, and will produce and react on ethylene during ripening. 10 µL ethylene /L air will at 15-21 °C ripen unripe bananas with a 24 hours treatment time. The sweetness of the bananas depends on the ripening stage. Unripe bananas have a green colour, approximately 20 % starch and 0.5 % sugar. During ripening the skin becomes yellow with brown spots, and the starch converts to sugar. Overripe bananas contain approximately 1.0 % starch and 19 % sugar (Wills et al. 2007).

## 2.6 Postharvest losses

Fruits are living biological systems and will change during storage. This means that they must be stored in the right way after harvest, and that the quality will deteriorate during storage. When the fruit is handled the right way the shelf life can be long, whereas wrong conditions the fruit can degrade quickly. Postharvest technology is developed to maintain good quality of the product, from the harvest to the end use (Wills et al. 2007).

### 2.6.1 Physical and quality losses

It is two kinds of postharvest losses, physical loss and quality loss. Physical loss comes from mechanical damage, pest and diseases; the fruit tissue becomes damaged and is no longer acceptable for eating. It can also occur from evaporation of intercellular water, which leads to

loss of weight and therefore money as the mass to sell is reduced. Quality loss may be from physiological and compositional changes that change the appearance, taste or texture. These changes will lead to lower prices or disposal of the product as second class products are not wanted even if they are edible (Wills et al. 2007).

### 2.6.2 Storage conditions

Different produce require different storage conditions, and they may also affect the other produce they are stored with. It is important to know what different produce require. Both the handling conditions and the storage environment are important. The storage environment includes the temperature and the composition of gasses. The temperature should be as low as possible, without causing chilling injuries. Most tropical fruits are susceptible for low temperatures and should not be stored below 10 °C. Temperatures over 30-35 °C may cause high temperature injury. High storage temperature decreases the shelf life. At optimum temperature, green bananas may be stored for 1-2 weeks, mango for 2-3 weeks and green pineapple may be stored for 4-5 weeks. A way of increasing the shelf life is to control the composition of oxygen and carbon gas. By increasing the level of carbon dioxide, from the regular 0.036 % in atmospheric air, and decreasing the level of oxygen, from the regular 21 % in atmospheric air, it is possible to reduce the respiration. When using this kind of storage it is important to know what levels of gasses the fruit can handle; too much $CO_2$ or too little $O_2$ will make the fruit collapse. Mangos and bananas cannot have more than 5 % $CO_2$ and pineapple cannot have less than 2 % $O_2$ (Wills et al. 2007).

The handling of the fruit has an impact on the mechanical damage. Careful handling, during harvest, transportation and storage, is essential to minimize the damage to the fruit. The storage condition is especially important when the fruits are stored for a long time and transported a long way. For small producers in developing countries it can be hard to get the right storage conditions and postharvest losses can cause considerable economic losses (Wills et al. 2007). It could be an opportunity to process the fruit themselves, and sell the processed fruit, or eat it on times when they don't have so much fruits.

## 2.7 Nutrients

Fruits consist of different amounts of water, carbohydrates, fat, protein, vitamin and minerals. They have around 75-85 % water and 10-20 % carbohydrates (Matvaretabellen.no 2006).

### 2.7.1 Carbohydrates

The carbohydrates can appear as complex polymers in the form of starch and dietary fibre, or as the mono – and disaccharides Glucose, Fructose and Sucrose. The mono – and disaccharides give the fruits the sweet taste. Humans can digest starch, mono – and disaccharides and these are important energy sources. The human body has not the enzymes to digest dietary fibre as cellulose and pectic substances. The body cannot use dietary fibre as energy sources, but fibre is promoted by health agencies as it is good for the digestion (Wills et al. 2007). Dietary fibre reduces the intestinal transit time and prevents constipation. It probably reduces the chance of heart disease and colon cancer (Damodaran et al. 2008). Norwegian health agencies recommend an intake of 25-35 mg of dietary fibre a day for grownups (helsedirektoratet.no 2005).

### 2.7.2 Vitamin and minerals

The most nutritious part of the fruit lies in the high content of vitamins and minerals. Vitamin C is a water soluble vitamin and is present as L-ascorbic acid (L-AA) and L-dehydroascorbic acid in the fruit (Damodaran et al. 2008). Humans cannot synthesize vitamin C and can only get it through the diet (Wills et al. 2007). Vitamin C is important for many of the human body's syntheses, like the synthesis of collagen and the synthesis of norepinephrine. Vitamin C is also an antioxidant. Lack of vitamin C may lead to scurvy which is recognized by easily bleeding and bruising, and hair and tooth loss (Higdon & Drake 2009). Norwegian health agencies recommend an intake of 75 mg of vitamin C a day for grownups (helsedirektoratet.no 2005).

Vitamin A is a fat-soluble vitamin. Vitamin A is a general term for nutritionally active unsaturated hydrocarbons. The most common vitamins A are retinol and β-carotene, but retinol related compounds and other carotenoids are also included. The different compounds must contain at least one intact non-oxygenated β-ionone ring and an isoprenoid side chain ending in an alcohol, aldehyde or carboxyl function (Damodaran et al. 2008). Retinol, the active vitamin A component, is not present in produce, but β-carotene can be converted to retinol in the human body (Wills et al. 2007). Vitamin A is essential for the human body and is important both for the sight and the immune system. Lack of vitamin A in the diet will lead to vitamin A deficiency. This will in the first place lead to blindness, but can also cause more severe illnesses and death. Vitamin A deficiency makes the immune system weaker, which leads to respiratory diseases and diarrhoea and in worst case mortality from infections like

measles (Higdon & Drake 2007). Norwegian health agencies recommend a daily intake of 700-900 mg of vitamin A for grownups (helsedirektoratet.no 2005).

Vitamin B is also a water soluble vitamin. The most common vitamins B are $B_6$, $B_{12}$ and folic acid ($B_9$) (Damodaran et al. 2008). Folic acid is present in green vegetables and some fruits, and is important in the RNA synthesis in the body. Deficiency will lead to anaemia. Folic acid is especially important during early pregnancy and deficiency at this stage can lead to spine bifida in the foetus (Wills et al. 2007). Norwegian health agencies recommend an intake of 300-400 mg of folic acid a day for grownups (helsedirektoratet.no 2005).

Minerals are a collectively of the chemical elements that are essential for life. Carbon, hydrogen, oxygen and nitrogen are not referred to as minerals. The mineral elements are present in low concentrations in food, but have important roles in living systems. The minerals can be divided into major minerals which include calcium, phosphorus, magnesium, sodium, potassium and chloride, and trace elements which include iron, iodine, zinc, selenium, chromium, copper, fluorine and tin (Damodaran et al. 2008).

### 2.7.3 Other nutrients

Fruit contains only small amounts of protein and fat and is not an important source for these nutrients. Organic acids as citric and oxalic acid, and especially the balance between these acids and the sugars, have a big influence on the taste of the fruit. Volatiles components as esters, alcohols, aldehydes and ketones also affect the taste. The composition of the different nutrients and volatiles components changes during the ripening face, and affects the taste and appearance of the fruit (Wills et al. 2007).

### 2.7.4 Food tables

The Norwegian “Matvaretabellen” is made by the Norwegian food Authority, the Health Directorate and the Department of Nutrition at the University of Oslo. The table contains the content of carbohydrates, fat, protein, minerals and trace elements in almost all food products eaten in Norway. The values are based on Norwegian analysis, and values from foreign food tables (Matvaretabellen.no 2006).

The Tanzania “Food Composition Table” is published by the Tanzanian Muhimbili University of Health and Allied Sciences (MUHAS), Tanzania Food and Nutrition Centre (TFNC) and the U.S. Harvard School of Public Health (HSPH). It contains the content of carbohydrates, fat, protein, minerals and trace elements in almost all food products eaten in Tanzania. Most

of the values are based on foods found in the World Food Dietary Assessment System (WFDAS) (Lukmanji et al. 2008).

## 2.8 Food safety

The levels of microorganisms are important for food safety under consumption after storage. The levels cannot be too high, and it is important that it not contains pathogen bacteria. The level of microorganisms must not spoil the product during storage. Many factors affect the development of microbes in food; it can be intrinsic factors as nutrients, pH and buffering capacity, redox potential, water activity, antimicrobial constituents and antimicrobial structures, environmental factors as relative humidity, temperature and gaseous atmosphere, implicit factors as specific growth rate and mutualism, and processing factors as slicing, washing, packaging, irradiation and pasteurization (Adams & Moss 2008). The microbiological activity can be controlled by different methods; one is by using agars. A sample of the product is prepared and put in a petri dish together with an agar. The petri dish is incubated at a certain temperature for a certain time and the number of colonies is counted. For testing different kinds of bacteria, different growth mediums are used. Plate Count Agar, PCA, is an agar which finds the total mesophilic plate count and can be used to get an indication of the microbiological quality. Rose Bengal/Chloramphenicol Agar is used to find the number of mould and yeasts. Violet Red/Bile/Glucose Agar, VRBA, is used to find the number of Enterobactericeae. Enterobactericeae includes coliform bacteria which are organisms capable of fermenting lactose in the presence of bile at 37 °C. Most strains of *Escherichia coli*, *Citrobacter* and *Enterobacter* are included in coliforms. Many of the Enterobactericeae originates from faecal sources, this is not the case for most of the *Citrobacter* and *Enterobacter*. Mac Conkey agar is used for coliforms. Agar contains a low concentration of agarose, 1.5-2 %, which makes the agar stiff. The gel is stable up to high temperatures, and must be heated to 100 °C to melt. Melted agar will remain liquid to around 40 °C. Pouring agar, after adding samples to the sterile petri dishes, is called embedding, while pouring agar to the sterile dishes, cool the agar and spread sample on top of the agar, is called surface spread. Surface spread will eliminate the risk of thermal shock for the bacteria. Dilution water is used during preparations of the samples. Sterile water can give the microorganism osmotic shock. Peptone water or ringers solution can be used to prevent this (Adams & Moss 2008).

## 2.9 Chemical evaluation

For measurement of some nutritional components in fruit, the following chemical analyses were carried out.

### 2.9.1 Spectrophotometry - Vitamin C

Spectrophotometry is a way of measuring the colour of a sample. Light is shining through a sample and a detector measures the light that passes through the sample. The light have wavelength between 250 and 2500 nm, depending on what to measure (nist.gov 2010). Ascorbic acid is an antioxidant and has reducing ability. 2,6 Dichlorophenolindophenol (DCPIP) is a selective oxidant which reacts with ascorbic acid, but reacts slowly with other reducing agents in food. DCPIP is a blue dye and will during reduction decrease in intensity of blue colour (Dachman et al. 1996). By mixing a sample containing ascorbic acid with DCPIP and measure the colour spectrophotometric, it is possible to find the ascorbic acid amount by using a standard curve.

### 2.9.2 High Performance Liquid Chromatography – Vitamin C

Liquid chromatography is an old method of separating compounds using a liquid and a column. The column is filled with a material, and the particles will use varying time through the column due to different size, charge and pH. The particles in the column are called the stationary phase, and the liquid is the mobile phase. Different stationary phases and mobile phases are used depending on the particles to be separated. Small particles have a resistant to flow; they need higher pressure to get the desired solvent flow through the column. This technique is called High Performance Liquid Chromatography, HPLC. HPLC is an important tool in analytical chemistry and is used to separate, identify and quantify the compounds present in a liquid (Waters 2011). The sample is injected in the column and the pressure is used to get it through the column were it is separated, and the different particles in the sample will come out of the column at different times. A UV detector is used to measure the amounts of the particles. UV light is shining through the steam of liquid coming out of the column and a UV collector is measuring how much light the sample absorbs. Comparing this absorptions with known standards, makes is possible to find the amount of the components (Clark 2000). By using other columns this method can be used to analyse other compounds, like organic acids and mono- and disaccharides.

### 2.9.3 Kjeldahl analysis - Protein

Fruit is not an important source for protein, but it contains some protein. Protein consists of a long chain of amino acids which contains nitrogen and the nitrogen can be used to find the protein content (Damodaran et al. 2008). It is assumed that dietary carbohydrates and fat not contain nitrogen, so that all the nitrogen in the diet is from the amino acids in protein. Approximately 16 % of the protein is nitrogen and the nitrogen content has to be multiplied with 6.25 (1/0.16= 6.25) to get the protein content. The nitrogen content in protein can vary in different food, multiplying with 6.25 will give an average value, while multiplying with another factor can give a more accurate value for a specific type of food (FAO 2003). The nitrogen content is found by using the Kjeldahl method, which can be divided in three parts; the digestion, the neutralisation and the titration. During the digestion the food sample is heated in the presence of sulphuric acid, anhydrous sodium sulphate and a catalyst. The nitrogen in the food will convert to ammonia, which binds to sulphate and gives ammonium sulphate. During the neutralisation sodium hydroxide is added; this converts the ammonium sulphate to ammonia gas. The ammonia gas is distilled into a tube with boric acid. The low pH in this tube converts the ammonia gas to ammonium ions, while the boric acid converts to borate ions. An indicator is used and the borate ions are titrated with standard sulphuric or hydrochloric acid to the end point of the reaction. The amount of acid used in the titration can be used to calculate the protein content (McClements 2003b).

### 2.9.4 Atomic absorption – Minerals

The mineral content can be determined by atomic absorption after wet- or dry-ashing. Dry-ashing is performed by burning the sample in a muffle furnace, which may lead to losses of volatile compounds. Wet-ashing is more complex and include heating with $HNO_3$ and $HClO_4$-$H_2SO_4$ (Lorenz et al. 1977). The ash is dissolved in an aqueous solution, and placed in an atomic absorption spectroscopy. The sample is heated and the minerals are vaporized and atomized. A light source is directed at the sample and the absorption of the light is measured. The absorption is compared to known absorption spectra to find the content of different minerals (McClements 2003a).

## 2.10 Product development and Sensory evaluation

Product development starts with an idea and ends in a ready product. It starts with a need in the marked for a new product, the idea is developed further, the necessary equipment is developed and a test production is conducted. Different tests, as shelf life tests and chemical

tests, are performed on these products. Another important part is different consumer tests and sensory evaluation (Earle et al. 2001). Consumer tests can be separated in two different categories, qualitative and quantitative. Qualitative consumer tests are focus group discussions, depth interviews and other tests with few participants. The results from these tests are not generalizable, but the tests are flexible and you see the product through the consumer's eyes. A focus group interview is a test where 8-10 persons have a conversation. The conversation is controlled by a leader, who asks the questions. The participants should have no training and not know each other. The result from this test is good for generating ideas and can give basis for questions to the qualitative consumer test. The results cannot be used in statistical analysis. Quantitative consumer tests are sensory product tests and concept-tests. The concept-tests are about the concept, while the sensory product tests are about how good the consumers like the product, liking/accept, or which product they like the most, preference. Hedonic testing is a way of controlling the liking. The consumers evaluate one product at a time, and give the product a score for how good they like it. This is a good way to compare several products; it gives the consumers liking of the product and the differences between the products. Many participants are given the same questions in the consumer test and the results are suitable for statistical analysis. These results can be compared with results from a describing analysis. A describing analysis is a product profile with some of the products sensory characteristics. This analysis should be done by a trained panel with 5-30 people. In sensory evaluations the samples should be given a random tree numbered code and served the consumers in random order (Lawlwss & Haymann 1999).

# 3 Materials and methods

In this assignment different fruits have been dried in two different types of solar driers. The dried fruits were analysed for microbiological quality, chemical changes and sensory evaluation. Three types of fruits were dried; mangoes, pineapples and bananas. A "homemade" cabinet dryer and a Hohenheim tunnel dryer (Innotech Ingenieursqesellschaft MbH, Altdorf, Germany) were used. One batch of each of the fruit varieties were dried in each dryer. The drying and parts of the analyses were conducted at SUA in Tanzania in the period 16th January 2011 to 16th March 2001, whereas the finishing analyses were conducted at UMB in Norway.

## 3.1 Drying

### 3.1.1 The drying place

The drying place consisted of a house for preparation of the samples, different types of cabinet dryers, a tunnel dryer and an electric dryer. The cabinet dryers and the tunnel dryer were placed outdoors, while the electric dryer, which was not used in this experiment, was inside the house. The house had indoor water most of the time, but no electricity. Before processing, the house was cleaned. The floors were washes, and the cutting trays, knives and benches were washed with soap and disinfected with water containing sodium hypochlorite. The personals were wearing lab coats, gloves and hairnets. In the processing place the windows were open. The cabinet dryers were washed, and the trays for the dryers were washed with soap and disinfected with water containing sodium hypochlorite.

### 3.1.2 Cabinet dryers

The cabinet dryers used were a local type. They were greenhouse type dryers with wooden frames, covered with plastic. The openings in the lower part on the back and the upper part in the front, to allow air flow, were covered with insect fly screen. The cabinets had room for six trays, three trays in two layers. Picture of the dryers are shown in the figures 3.1 and 3.2.

**Figure 3. 1 Picture of a cabinet dryer. There is fly screen over the door for outlet of the air.**

**Figure 3. 2 Picture of a cabinet dryer from the back. The fly screen is for inlet of the air.**

#### *3.1.2.1 Mango- 'Dodo' and 'Kaitt'*

Ripe mangoes were washed and dried. They were peeled and sliced in "sticks" which were 0.5-1 cm thick. The sticks were placed on trays and put in the cabinet dryer at 11:00 am After 27 hours (02:00 pm the next day) half of the samples were removed, and after 51 hours (02:00 pm the day after) the remaining samples were removed.

#### *3.1.2.2 Banana- 'Kisuuavi'*

Ripe bananas were washed and dried. They were peeled and sliced in 2-3 mm thick slices. The slices were put on trays and put in the dryers at 11:00 am. They were removed after 51 hours (02:00 am two days later).

#### *3.1.2.3 Pineapple*

Ripe pineapples were washed, and the levees were removed. They were peeled and cut in 2-3 mm thick slices which were cut in four and the stem in the middle was removed. The pieces were put in trays, placed in the cabinet drier at 11:00 am and removed after 51 hours (02:00 pm two days later).

#### *3.1.2.4 Contaminated samples*

To control how microbes behaved during drying and storage, some contaminated samples of 'Dodo' mangoes were prepared. They were prepared like the other mangoes, but contaminated with water infected with dry faeces from cow, goat and pork. These samples were put in the dryer at 11:00 am and removed after 27 hours (02:00 pm the next day).

### 3.1.3 Tunnel dryer

The Hohenheim tunnel dryer had a heating and a drying area, and a fan driven by the electricity from a solar module. The other end of the tunnel was covered with fly screen to protect from flies. The tunnel dryer is shown in the figures 3.3 and 3.4.

**Figure 3. 3 The tunnel dryer with the solar module and the heating area.**

**Figure 3. 4 The tunnel dryer. The drying area is the closest part in the picture.**

#### *3.1.3.1 Mango- 'Dodo' and 'Kent'*

Ripe mangoes were prepared in the same way as for the cabinet dryer. 'Dodo' and 'Kent' were sliced and laid in the dryer; the tunnel was filled and closed at 11:00 am. The samples were removed after five days (17:00 pm, five days later). The weather conditions were not good during the drying of the mangos; it was raining some hours every day and the air had high humidity. Many of the mango samples had brown spots when they were collected.

#### *3.1.3.2 Pineapples*

Ripe pineapples were prepared in the same way as for the cabinet dryer. The pineapples were sliced and laid in the dryer; the tunnel was filled and closed at 11:00 am. The samples were removed after 51 hours (02:00 pm two days later).

#### *3.1.3.3 Bananas*

Ripe bananas were prepared in the same way as for the cabinet dryer. They were sliced and laid in the dryer; the tunnel was filled and closed at 01:00 pm. The samples were removed after four days (17:00 pm four days later). The weather conditions were not good during the drying of the bananas; it was raining some hours every day and the air had high humidity.

### 3.1.4 Storing of the samples

The samples were packed in plastic bags. The samples from the tunnel dryer were stored in a freezer at -18 °C, whereas the samples from the cabinet dryer were stored both at -18 °C and at room temperature for microbiological control. During the trip to Norway the samples were out of the freezer for one day.

## 3.2 Microbiological analyses

### 3.2.1 Tanzania

The first microbiological analyses were carried out after all the samples from the cabinet dryer were dried. The samples were stored for three to ten days before the analyses. All the samples from the cabinet dryer, both the ones stored at room temperature and at -18 °C, were analysed.

#### *3.2.1.1 Preparation of equipment, agar and dilution water*

Before the microbiological analyses started all the glass were sterilized at 121 °C in 15 minutes. The Standard Plant Count Agar (OXOID LTD, Basingstoke, Hampshire, England) was weighed out using a Sartorius AC 211 S -00MS balance (Gottingen, Germany) and suspended in distilled water (23.5 g/L water). Mac Concey Agar No 1 (Fluka analytical, Sigma-Aldrich Corporation, St. Louis, Missouri, USA) was weighed out and suspended in distilled water (52 g/L water). Peptone (OXOID LTD) was weighed out and suspended in distilled water (15 g/L water). The peptone water was divided in tubes of 9.9 ml. The agars and the peptone water were sterilized at 121 °C in 15 minutes in a pressure boiler (Presto, Hillsville, USA) on a stove. Most of the sterilization was performed by the lab technicians.

#### *3.2.1.2 Methods - Microbiological analyse*

10 g of the samples were weighed out and 90 ml of boiled distilled water were added. The first samples, the ones that were not frozen, were homogenized with a hand blender (SHB-154J, 200W, SONASHI, Dubai, United Arab Emirates), however the hand blender broke, and the last samples were homogenized with a mortar. The suspensions were diluted in peptone water and on the petri dishes embedding and the dilutions $10^{-1}$, $10^{-3}$ and $10^{-5}$ were used. The agars were prepared in 0.5 litre and 1.0 litre bottles, and became cold and lumpy during the pouring.

The hand blender and mortar were washed with water and sterilized with ethanol between the samples.

The petri dishes were left until they got stiff; they were wrapped in aluminium foil and incubated at 30 °C. The Mac Concey dishes were incubated for 24 hours, and the PCA dishes for 2.5 days.

To see the microorganisms' development during storing, a new analysis was prepared. To prevent the problems with cold agar and the problems with power breach, dishes were prepared three days before the analysis. The washed petri dishes were wrapped in aluminium foil and sterilized in a pressure boiler. The Pressure Gauge was not working, and the temperature in the boiler never turned above 100 °C. It boiled for 30 minutes. The agar was weighed, mixed with distilled water and sterilized the same way as the petri dishes. The sterile agar was cooled to 50-60 °C and poured in the sterile petri dishes. The dishes were wrapped in aluminium foil and stored at 4 °C for three days. When the analysis was supposed to take place, over half of the "sterile" dishes had growth of microorganisms. This was a sign of inadequate sterilization. The microbiological analysis was therefore not carried out.

### 3.2.2 Norway

Microbiological analyses were also conducted in Norway. First a feed trial was conducted to compare different ways of preparing the samples. Three different ways were tested; using a mortar, using a stomacher and using a tube. The tube method was chosen as the best and easiest way, and used on all the samples. In the feed trial mango was used. All the samples from the cabinet dryer and the tunnel dryer, were analysed, both the frozen ones and the ones stored at room temperature.

#### *3.2.2.1 Preparation agar and dilution water*

The Plant Count Agar, Casein-peptone glucose yeast extract agar for microbiology, (Merck KGaA, Darmstact, Germany) was weighed out with a Mettler PJ 300 balance (Greifensee, Switzerland), suspended in distilled water (22.5 g/L water) and brought to the boiling point for total suspension. The agar was divided in 200 ml bottles and sterilized at 121 °C in 15 minutes in an autoclave (Getinge AB, Getinge, Sweden). The agar was cooled down and stored at 4 °C. The day the agar was used it was liquidized in a boiling water bath and cooled to 48 °C in another water bath. The Violet Red Bile Agar (OXOID LTD) was weighed out in small bottles, distilled water was added (38.5 g/L water) and it was heated in the boiling water bath together with the PCA agar and cooled to 48 °C.

Rose-Bengal Chloramphenicol agar (OXOID LTD) was weighed out, suspended in distilled water (16 g/0.5 L water), and brought to the boiling point for total suspension. The agar was

sterilized at 121 °C in five minutes. The agar was cooled to 48 °C, "Chloramphenicol selective Supplement" was added and the agar was poured in petri dishes in a sterile bench.

Ringers solution was made by suspending one Ringers tablet (Merck KGaA), in 500 ml distilled water. The solution was divided in tubes of 9 ml, 9.9 ml and 45 ml, and sterilized at 121 °C in 15 minutes. Peptone water was made by weighing out 10.0 g Bacteriological peptone (OXOID LTD), and 5.0 g sodium chloride, per L distilled water, mixing the powder with water and adjust the pH to 7.2 ±0.2 by adding 1.0 M NaOH. The peptone water was divided in tubes of 9 ml and sterilized at 121 °C in 15 minutes.

#### *3.2.2.2 Methods – Feed trial*

In the feed trial mango was used.

In the mortar 5 g sample and 45 ml Ringers solution were added, and morted in four minutes. The mortar was sterilized with 70 % ethanol. In the stomacher 5 g sample and 45 ml Ringers solution were added in the sterile Seward bag (Seward Limited, West Sussex, United Kingdom), and the Laboratory Blender Stomacher 400 (Seward Limited) ran in four minutes. In the tubes 1 g sample was added to 9 ml of Ringers solution vortexed on a Vortex Genie 2 (Scientific industries, Bohenia, NY, USA) for one minute and turned in a Multi RS-60, Programmable rotator-mixer (Biosan, Riga, Latvia) for 15 minutes. The samples were cut in pieces using a sterile knife before adding them to the tubes. The solutions were diluted in Ringers solution. On the petri dishes the dilutions $10^{-1}$, $10^{-3}$ and $10^{-5}$ were used for PCA and $10^{-1}$ and $10^{-2}$ for VRBA agar. Embedding was used for both agars. The PCA dishes were incubated for three days at 30 °C and the VRBA dishes were incubated for 24 hours at 37 °C.

From the experiences form the feed trial it was decided to use the tube method, that the fruits should be tested for mould and yeast using Rose Bengal agar and to use peptone water for the mixing in the rotator-mixer.

#### *3.2.2.3 Methods –Microbiological analysis*

1 g sample was weighed out, cut and put in 9 ml of peptone water. The sample was vortexed for 20 seconds, turned on a rotator-mixer for 30 minutes and diluted with Ringers solution. On PCA agar embedding and the dilutions $10^{-1}$, $10^{-2}$ and $10^{-3}$ were used; it was incubated at 30 °C for three days. On Rose-Bengal surface spread and the dilution $10^{-1}$ and $10^{-2}$ were used; it was incubated at 22 °C for five days. On VRBA agar embedding and the dilution $10^{-1}$ was used; it was incubated at 37 °C for 24 hours.

## 3.3 Chemical analyses

The moisture content, protein and ash analyses were conducted in Tanzania. Vitamin C analyses were performed both in Tanzania and Norway. The frozen samples from both the cabinet and the tunnel dryer were analysed. The analyses were performed as described by the lab technicians if nothing else is specified.

### 3.3.1 Moisture content

The samples were analysed by drying the samples to minimal moisture content. A dish was weighed, ca. 5 g sample was added and the accurate weight was noted. The sample was put in an incubator at 80 °C for 3 days, weighed once more, and the moisture content was calculated. The analysis was done in duplicate.

### 3.3.2 Protein

The samples were analysed with the Kjeldahl method by the lab technicians. 0.1 – 0.2 g prepared sample was weighed and transferred to a Kjeldahl tube. 10 ml concentrated sulphuric acid and a catalyst tablet containing 1 g Sodium sulphate and 0.1 g Copper sulphate was added. The sample was digested do a bright green colour appeared, the digest was cooled and 75 ml distilled water was added. The tube was placed in distillation equipment, 75 ml 40 % sodium hydroxide was added and the ammonia was distilled onto 25 ml 4 % boric acid. The distillation was carried out until 150 ml solution obtained. The solution was titrated with 0.1 N Hydrochloric acid until the colour changed from green to purple. Two parallels of each sample were analysed.

One of the samples had very high result. This sample was analysed once more in Norway. The sample was prepared by homogenise the dried sample with water in the ratio 1:2 using a hand blender (HR 1364 600W, Philips, Amsterdam, Netherlands). 0.1-0.2 g prepared sample was weighed and transferred to a Kjeldahl tube. The analysis was conducted using 3 ml sulphuric acid and 0.05 M HCl. Six parallels of the sample were analysed.

### 3.3.3 Minerals

1 g sample was weighed out and burned in a RWF 12/5 Muffle furnace (Carbolite, Hope Valley, United Kingdom) at 500 °C in five hours. Many of the samples contained black material after the burning; which indicated that all the carbon was not burned. The samples should have been burned once more, that were not done. 20 ml 1.0 N HCl was added to the samples, the carbon was mashed and the samples stood for 24 hours. The samples were filtered through a Whatman filter paper (Whatman International Ltd., Brentford, UK) to 100

ml volumetric flasks and these were filled with distilled water. The samples were analysed by atomic absorption by the lab technicians. Two parallels of each sample were analysed.

### 3.3.4 Vitamin C

Two vitamin C analyses were conducted; one in Tanzania and one in Norway.

#### *3.3.4.1 Tanzania*

In Tanzania the procedure described by Dashman et al. in Laboratory Manual for Human Nutrition (Dachman et al. 1996) was followed. Five of the samples were analysed.

##### 3.3.4.1.1 Preparation of solutions

0.1 M citric acid (19.21g/ 1000 ml water) and 0.1 M sodium citrate (29.41 g $C_6H_5O_7Na_3$ $H_2O$/1000 ml water) were made. 330 ml 0.1 M citric acid and 170 ml 0.1 M sodium citrate were mixed with 500 ml water to make a citrate buffer. An ascorbic acid (AA) stock solution (60 mg AA/100 ml citrate buffer), an ascorbic acid working solution (20 mg AA/100 ml citrate buffer), a 0.45 % DCPIP stock solution and a DCPIP working solution were made.

##### 3.3.4.1.2 Methods - Spectrophotometry

To make a standard curve the ascorbic acid working solution was diluted to six AA solutions in concentrations from 0 to 2.0mg AA /ml citric acid. 3 ml buffer and 2 ml of different AA solutions were transferred to tubes and 1 ml DCPIP working solution was added. After 10 minutes the solutions were measured spectrophotometric at 520 nm with a 6400/6405 Spectrophotometer (Wagtech International Ltd, Berkshire, United Kingdom).

The results were supposed to give a standard curve for the vitamin C analyses, but the results gave no curve. The procedure was done several times, but with no good results and no standard curve.

The fruit samples were prepared by putting 5 g fruit in 65 ml citric buffer. The samples were rehydrated for about two hours, homogenized with a mortar, filtered through a Whatman filtered paper and 50 ml more of citric buffer was added. 2 ml of this solution was mixed with 3 ml citric buffer, and 1 ml DCPIP working solution was added, this solution stood for 10 minutes before it was measured, using a spectrophotometer at 520 nm. These values were supposed to be calculated to results by using the standard curve.

#### *3.3.4.2 Norway*

In Norway a HPLC procedure was used. The samples were prepared and analysed as described by Volden (Volden 2008). All the frozen samples from both the dryers were analysed.

The samples were weighted out and 1% oxalic acid was added. The mangoes were diluted 30 times, and the bananas and pineapples were diluted 15 times. The samples were homogenised with a hand blender (300 watt, Braun, Kronberg im Taunus, Germany), filtered through a Whatman 113 V folded filter paper, and applied onto a Sep-Pac C18 (Waters Corp., Milford, MA, USA) which were activated with 5 ml methanol and 5 ml water and washed with the first 3 ml of the samples. The samples were filtered through a 0.45 µm syringe filter (VWR International LC, West Chaster, PA, USA) before they were ready for analysing. The samples were analysed using an Agilent 1100 Series LC system (Agilent Technologies, Waldbronn, Germany) with a quaternary pump, an inline degasser, an autosampler, a column oven and a UV detector. The columns used were a Zorbax SB-C18 (250 x 4.6 mm, 5 µm) and a complementary Zorbax XDB C18 (4 x 4 mm, 5 µm) guard column (Agilent Technologies, Waldbronn, Germany). The injection volumes were 5 µl, the flow of 0.05 M KH2PO4 was 1 ml per minute at 25 °C and the detection was at 254 nm (Volden 2008). The results were calculated from a standard curve for vitamin C.

### 3.3.5 Result treatment

The results from the chemical analyses were in mg, g or % of the sample. Since the samples had different moisture content it was difficult to compare them. The results were calculated to content of the nutrient in dry matter of the sample for easier comparison. The measured moisture contents were used for this calculation. For comparing the results with the content in fresh fruit, the values from the Norwegian "Matvaretabellen" and the Tanzanian "Food composition table" were used. The values were calculated as g nutrient per 100 g dry matter. For the values from "Matvaretabellen" the given moisture contents were used and from the "Food composition table" the moisture contents were calculated by subtracting the carbohydrate, protein and fat values from 100.

## 3.4 Sensory evaluations

Two different kinds of sensory evaluations; focus group interview and consumer tests, were conducted.

### 3.4.1 Focus group

The focus group was conducted in Tanzania with eight students, whereas four master students, two males and two2 females, from food science and four master students, two males and two females, from agricultural economics. They were between 28 and 35 years. It was first a conversation about whether they had eaten dried fruits before, how often and whether they liked it or not. They then tasted the ten fruit samples, said what they thought about them and which ones they liked the most.

### 3.4.2 Consumer test

The consumer test, in the form of a sensory product test was conducted in both Tanzania and Norway. The same questionnaire was used both places. In Tanzania the questionnaire was in English, some of the consumers were able to fill it out themselves and some filled it out with translation help. The test was conducted outside a local supermarket and at SUA campus. In Norway the questionnaire was in Norwegian, and the test was conducted at UMB campus and among the employees at a nursing home. In the test seven samples were chosen for the consumers to evaluate, Mango 'Dodo' cabinet 51 hours, Mango 'Dodo' tunnel, Mango Kaitt cabinet 51 hours, Pineapple cabinet and tunnel and Banana cabinet and tunnel. The samples were chosen on the basis of the focus group interview. The consumers tasted the fruits in random order, but always samples from the same variety consecutively; like: banana, banana, pineapple, pineapple, mango, mango, mango. The samples were marked with a three numbered random code. To get a product profile the consumers were asked about the characteristics hardness, sweetness, acidity and aroma of the samples, in addition to liking. The two first pages of the questionnaire are shoved in appendix 2.

# 4 Results

## 4.1 Drying

Two different types of dryers were used, cabinet dryers and a tunnel dryer. In the cabinet dryers the Mango samples were removed at two different times, 27 hours and 51 hours, the pineapple and the banana samples were all removed after 51 hours. In the tunnel dryer the samples were supposed to be dried for 51 hours, like in the cabinet dryer, to see whether the dryers gave different results. Some drying had been conducted at SUA before this assignment started. They had dried mango in two-three days, which gave a real dry and crispy product, but with little fruit flavour. One of the goals with this assignment was to test different times of drying and hopefully make a product with more taste.

The drying was dependent on the weather conditions. During the drying in the cabinets the weather conditions were good, sunny and with no rain. During the drying in the tunnel dryer the weather conditions were not that good. It was sunny when the pineapples were dried, but cloudy and rain during the drying of the mangoes and bananas, which lead to poor drying conditions. The fruit lay in the dryer longer than the estimated two days. For removing the samples from the tunnel dryer, the whole tunnel had to be opened. To prevent the samples from becoming wet, the removing had to be done in dry weather. Three different kinds of mangoes were supposed to be dried in both dryers, but unripen mangoes and misunderstanding resulted in changes. ‘Dodo’ and ‘Kaitt’ were dried in the cabinet dryers whereas ‘Dodo’ and ‘Kent’ were dried in the tunnel dryer. From the cabinet dryers the samples were both frozen and stored at room temperature, while from the tunnel dryer all samples were frozen. Table 4.1 shows all the different varieties. Pictures of the frozen samples are shown in the figures 4.1-4.10.

**Table 4. 1 An overview over the different samples dried. The last column is a shortening, which is used for the results in some of the analyses.**

| Sort and Variety | Dryer | Time | Storing | Short name |
|---|---|---|---|---|
| Mango ‘Dodo’ | Cabinet | 27 hours | Room temp. | MDC27R |
| Mango ‘Dodo’ | Cabinet | 27 hours | Frozen | MDC27F |
| Mango ‘Dodo’ | Cabinet | 51 hours | Room temp. | MDC51R |
| Mango ‘Dodo’ | Cabinet | 51 hours | Frozen | MDC51F |
| Mango ‘Dodo’ | Tunnel | 5 days | Frozen | MDTF |
| Mango ‘Kaitt’ | Cabinet | 27 hours | Room temp. | MKaC27R |
| Mango ‘Kaitt’ | Cabinet | 27 hours | Frozen | MKaC27F |
| Mango ‘Kaitt’ | Cabinet | 51 hours | Room temp. | MKaC51R |
| Mango ‘Kaitt’ | Cabinet | 51 hours | Frozen | MKaC51F |

| Sort and Variety | Dryer | Time | Storing | Short name |
|---|---|---|---|---|
| Mango 'Kent' | Tunnel | 5 days | Frozen | MKeTF |
| Mango, contaminated | Cabinet | 27 hours | Room temp. | McontR |
| Mango, contaminated | Cabinet | 27 hours | Frozen | McontF |
| Pineapple | Cabinet | 51 hours | Room temp. | PCR |
| Pineapple | Cabinet | 51 hours | Frozen | PCF |
| Pineapple | Tunnel | 51 hours | Frozen | PTF |
| Banana | Cabinet | 4 days | Room temp. | BCR |
| Banana | Cabinet | 4 days | Frozen | BCF |
| Banana | Tunnel | 4 days | Frozen | BTF |

**Figure 4. 1 Picture of Mango 'Dodo' cabinet, 27 hours**

**Figure 4. 2 Picture of Mango 'Dodo' cabinet, 51 hours**

**Figure 4. 3 Picture of Mango 'Dodo' tunnel, 5 days**

**Figure 4. 4 Picture of Mango 'Kaitt' cabinet, 27 hours**

**Figure 4. 5 Picture of Mango Kaitt cabinet, 51 hours**

**Figure 4. 6 Picture of Mango 'Kent' tunnel, 5 days**

**Figure 4. 7 Picture of Pineapple, cabinet, 51 hours**

**Figure 4. 8 Picture of Pineapple, tunnel, 51 hours**

**Figure 4. 9 Picture of Banana, cabinet, 51 hours**

**Figure 4. 10 Picture of Banana, tunnel, 4 days**

## 4.2 Microbiological analyses

### 4.2.1 Microbiological analyses in Tanzania

The microbiological analyses in Tanzania were conducted when all the drying in the cabinet dryers was finished; the samples were stored in 3-10 days. The samples were tested for total number of mesophilic bacteria on PCA agar and for coliforms on Mac Conkey agar. Many of the results were a bit odd; they had little correlations among the dilutions, and the parallels had big standard deviations. The weighted mean was calculated where the dilutions had big variations. The correlations from the microbiological analyses in Tanzania are shown in table 4.2 and the microbiological growth is shown in figure 4.11.

**Table 4. 2 The correlations between the different parameters and the growth on the different agars. The upper values are the Pearson correlations and the bottom values are the P-Values. Fruit is fruit variety, Time is drying time, 27 hours, 54 hours, four days and five days, and post treatment is frozen and stored at room temperature.**

| Agar | Fruit | Time | Post treatment | PCA |
|---|---|---|---|---|
| PCA | -0.171<br>0.559 | -0.242<br>0.405 | -0.332<br>0.246 | |
| Mac Concey | -0.479<br>0.083 | -0.190<br>0.514 | 0.245<br>0.398 | 0.343<br>0.230 |

For correlations the p-value must be under 0.05. The p-value shows that the parameters not correlate.

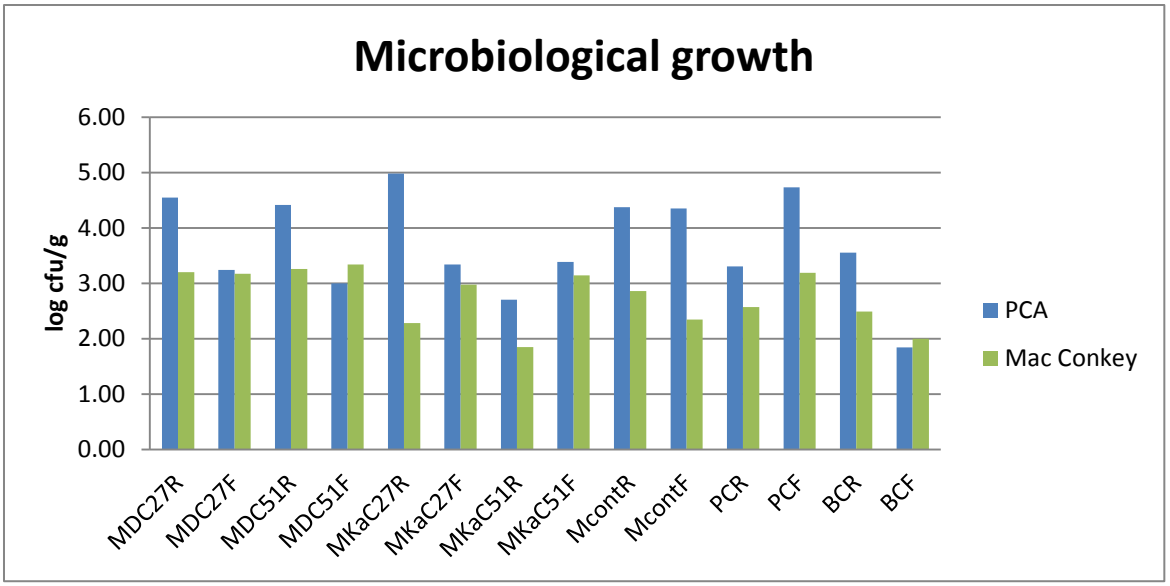



**Figure 4. 11 The microbiological growth on PCA and Mac Conkey agar from the microbiological analyses in Tanzania.**

The results show that most of the frozen samples had less growth of mesophilic bacteria compared to the samples stored at room temperature, but the correlation plot implies that the difference not was significant. All the samples had a lot of coliform growth, but there were not big differences between the samples. It was no correlation between the growth of mesophilic bacteria and the growth of coliform bacteria.

New microbiological analyses were supposed to be conducted four weeks after the first ones. They were not carried out because of unsterile agar dishes.

### 4.2.2 Microbiological analyses in Norway

A feed trial was conducted in Norway to find a method easy to conduct and that gave good results. The trial showed that all three methods gave similar results. The tube method was chosen. The $10^{-1}$ had much growth and the $10^{-5}$ dilution had almost none growth; the PCA dishes had growth of mould and yeast. It was decided to use the dilutions$10^{-1}$, $10^{-2}$ and $10^{-3}$ dilutions for PCA, and to use Rose-Bengal agar for control of mould and yeast.

All the samples were analysed, both the frozen ones and the ones stored at room temperature. The correlations are shown in table 4.3 and the growth is shown in figure 4.12.

**Table 4. 3 The correlations between the different parameters and the growth on the different agars. The upper values are the Pearson correlations and the bottom values are the p-values. Fruit is fruit variety, time is drying time, 27 hours, 54 hours, four days and five days, drying method is cabinet or tunnel dryer, and post treatment is frozen and stored at room temperature.**

| | Fruit | Time | Drying method | Post treatment | PCA | Rose-B. |
|---|---|---|---|---|---|---|
| PCA | 0.028<br>0.913 | -0.044<br>0.862 | -0.021<br>0.935 | 0.492<br>0.038 | | |
| Rose-B. | 0.120<br>0.635 | 0.257<br>0.303 | 0.205<br>0.415 | 0.688<br>0.002 | 0.803<br>0.000 | |
| VRBA | -0.256<br>0.305 | -0.276<br>0.268 | -0.062<br>0.806 | 0.268<br>0.281 | 0.289<br>0.245 | 0.225<br>0.370 |

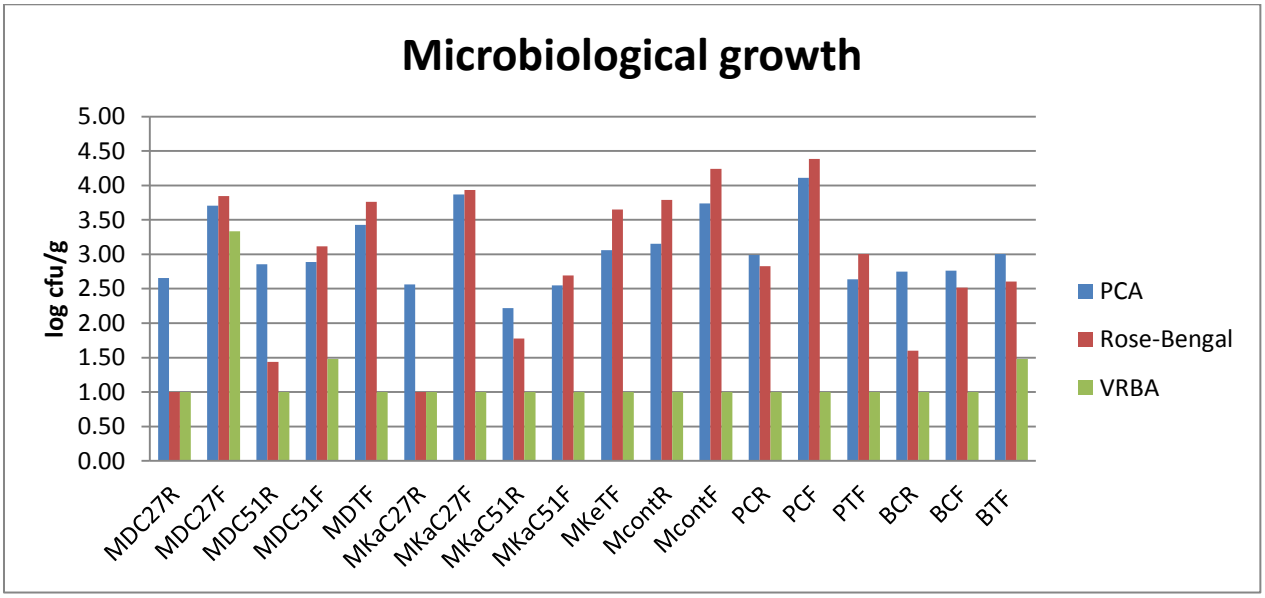



**Figure 4.12 The microbiological growth on the different agars. The ones with the value log 1 had no growth on the $10^{-1}$ dilution, and the values are <1 log cfu/g.**

Most of the mesophilic growth and growth of mould and yeast were higher on the frozen samples than on the samples stored at room temperature. The correlation plot shows that the difference was significant. All the samples with growth on Rose-Bengal agar had growth of both mould and yeast. A correlation was found between the mesophilic growth and the growth of mould and yeast. Most of the samples did not have growth of coliform bacteria but the frozen 'Dodo' sample dried for 27 hours in a cabinet dryer had high growth.

### 4.2.3 All microbiological analyses

The correlations between the mesophilic growth in Norway and Tanzania are shown in table 4.4.

**Table 4. 4 The correlations between the parameters, where the upper values are the Pearson correlations and the second values are the p-values. Fruit is fruit variety, time is drying time, 27 hours, 54 hours, four days and five days, and post treatment is frozen and stored at room temperature.**

| | Fruit | Time | Post treatment | PCA, Norway |
|---|---|---|---|---|
| PCA, Norway | 0.154<br>0.600 | -0.161<br>0.581 | 0.574<br>0.032 | |
| PCA, Tanzania | -0.171<br>0.559 | -0.242<br>0.405 | -0.332<br>0.246 | 0.243<br>0.403 |

Most of the mesophilic growth in Tanzania was higher than the growth in Norway, but the correlation plot shows that the growth had no correlations.

## 4.3 Chemical analyses

### 4.3.1 Moisture content

To find the moisture content in the samples after drying a moisture analysis was conducted. The results are shown in table 4.5.

**Table 4. 5 The moisture content with standard deviations in the dried fruit samples.**

| Sample | Moisture content in % ± STD |
|---|---|
| Mango 'Dodo' cabinet, 27 hours | **18.9** ±3.4 |
| Mango 'Dodo' cabinet, 51 hours | **11.6** ±0.2 |
| Mango 'Dodo' tunnel, 5 days | **7.9** ±0.4 |
| Mango 'Kaitt' cabinet, 27 hours | **12.2** ±0.3 |
| Mango 'Kaitt' cabinet, 51 hours | **11.6** ±0.1 |
| Mango 'Kent' tunnel, 5 days | **8.1** ±0.2 |
| Pineapple, cabinet, 51 hours | **11.5** ±0.1 |
| Pineapple, tunnel, 51 hours | **7.5** ±0.2 |
| Banana, cabinet, 51 hours | **10.1** ±0.3 |
| Banana, tunnel, 4 days | **6.5** ±0.1 |

The results show that longer drying time gave lower moisture content.

### 4.3.2 Protein

The protein analysis was conducted by the lab-technicians in Tanzania, using the Kjeldahl-method. Due to extremely deviating value for Mango, 'Dodo', cabinet, 27 hours this sample was repeated in Norway (analysed separately). The new value is presented here. The results are shown in table 4.6. The Norwegian "Matvaretabellen" and the Tanzanian "Food composition table" were used for comparison. The values were calculated to g protein per 100 g dry matter. These results are shown in figure 4.13.

**Table 4. 6 The protein content with standard deviations in the dried fruits, given in g protein per 100 g sample. The value for "Mango 'Dodo' cabinet, 27 hours" is from the second protein analysis.**

| Sample | g protein per 100 g sample ± STD |
|---|---|
| Mango 'Dodo' cabinet, 27 hours | **2.80** ± 0.14 |
| Mango 'Dodo' cabinet, 51 hours | **5.18** ± 0.07 |
| Mango 'Dodo' tunnel, 5 days | **6.38** ± 0.21 |
| Mango 'Kaitt' cabinet, 27 hours | **6.55** ± 0.44 |
| Mango 'Kaitt' cabinet, 51 hours | **4.46** ± 0.15 |
| Mango 'Kent', tunnel, 5 days | **3.28** ± 0.06 |
| Pineapple, cabinet, 51 hours | **3.03** ± 0.13 |
| Pineapple, tunnel, 51 hours | **4.88** ± 0.03 |
| Banana, cabinet, 51 hours | **3.58** ± 0.01 |
| Banana, tunnel, 4 days | **4.31** ± 0.05 |

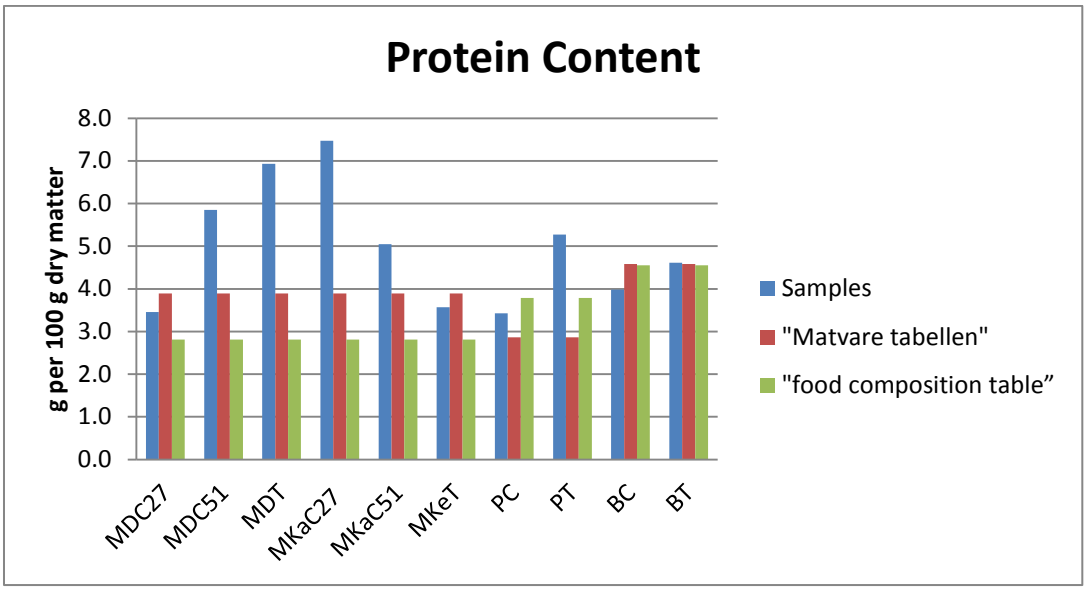



**Figure 4. 13 The protein content in g per 100 g dry matter. The blue columns are the produced samples, the red columns are calculated from the Norwegian "Matvaretabellen" (Matvaretabellen.no 2006) and the green columns are calculated from the "food composition table" (Z., E. et al. 2008). The MDC27 sample value is from the second protein analysis.**

The results show that the sample values were higher than the given protein values from the tables. This can be because the protein content in fruit can vary with variety and maturity, the measured moisture content in the samples can be wrong or the analysis may have been wrongly performed. The value from the second protein analysis (MDC27) was lower than for the other mango samples. The standard deviations were quite low, but the variation among the samples from the same variety was big.

### 4.3.3 Minerals

The ash samples were prepared and analysed by atomic absorption by the lab technicians in Tanzania. The results are shown in table 4.7.

**Table 4. 7 part I The mineral content with standard deviations in the fruit samples given in mg per 100 g sample.**

| Sample | Potassium (P) mg/100 g ± STD | Cupper (Cu) mg/100 g ± STD | Iron (Fe) mg/100 g ± STD |
|---|---|---|---|
| Mango 'Dodo' cabinet, 27 hours | **42.1** ± 7.5 | **0.67** ± 0.33 | **2.65** ± 0.02 |
| Mango 'Dodo' cabinet, 51 hours | **48.5** ± 13.3 | **0.75** ± 0.07 | **3.40** ± 0.21 |
| Mango 'Dodo' tunnel, 5 days | **49.4** ± 14.5 | **0.26** ± 0.09 | **1.86** ± 0.28 |
| Mango 'Kaitt' cabinet, 27 hours | **23.8** ± 2.7 | **0.33** ± 0.01 | **2.30** ± 0.20 |
| Mango 'Kaitt' cabinet, 51 hours | **10.4** ± 3.4 | **0.25** ± 0.09 | **4.73** ± 0.64 |
| Mango 'Kent' tunnel, 5 days | **41.6** ± 13.5 | **0.33** ± 0.00 | **2.62** ± 0.49 |
| Pineapple, cabinet, 51 hours | **23.1** ± 3.8 | **0.16** ± 0.01 | **2.48** ± 0.06 |
| Pineapple, tunnel, 51 hours | **49.5** ± 10.3 | **0.16** ± 0.01 | **2.23** ± 0.76 |
| Banana, cabinet, 51 hours | **68.0** ± 46.5 | **0.17** ± 0.00 | **6.18** ± 1.89 |
| Banana, tunnel, 4 days | **45.1** ± 9.2 | **0.17** ± 0.01 | **2.39** ± 0.86 |

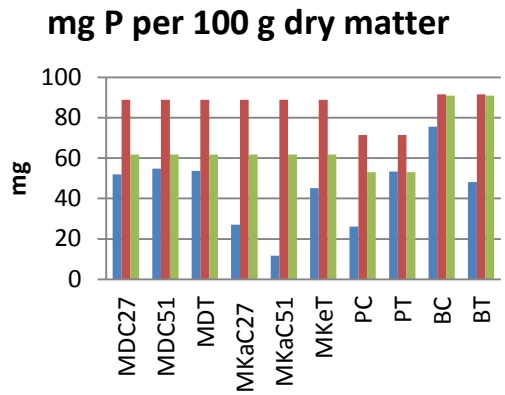
**Table 4.7, part II**

| Sample | Zinc (Zn) mg/100 g ± STD | Manganese (Mn) mg/100 g ± STD | Calcium (Ca) mg/100 g ± STD |
|---|---|---|---|
| Mango 'Dodo' cabinet, 27 hours | **0.52** ± 0.13 | **0.53** ± 0.16 | **116.7** ± 32.5 |
| Mango 'Dodo' cabinet, 51 hours | **0.78** ± 0.02 | **0.61** ± 0.24 | **87.1** ± 21.6 |
| Mango 'Dodo' tunnel, 5 days | **1.68** ± 1.24 | **0.02** ± 0.00 | **82.0** ± 3.5 |
| Mango 'Kaitt' cabinet, 27 hours | **0.20** ± 0.02 | **0.35** ± 0.01 | **85.7** ± 5.4 |
| Mango 'Kaitt' cabinet, 51 hours | **0.26** ±0.02 | **0.20** ± 0.01 | **87.4** ± 1.2 |
| Mango 'Kent' tunnel, 5 days | **0.67** ± 0.02 | **0.02** ± 0.00 | **110.5** ± 18.7 |
| Pineapple, cabinet, 51 hours | **0.39** ± 0.12 | **8.10** ± 1.94 | **151.5** ± 19.5 |
| Pineapple, tunnel, 51 hours | **0.98** ± 0.28 | **6.61** ± 0.89 | **129.2** ± 13.5 |
| Banana, cabinet, 51 hours | **0.69** ± 0.03 | **0.02** ± 0.00 | **82.9** ± 3.3 |
| Banana, tunnel, 4 days | **0.48** ± 0.09 | **0.02** ± 0.00 | **65.0** ± 1.9 |

**Table 4.7, part III**

| Sample | Magnesium (Mg) mg/100 g ± STD | Potasium (K) mg/100 g ± STD | Sodium (Na) mg/100 g ± STD |
|---|---|---|---|
| Mango 'Dodo' cabinet, 27 hours | **10.1** ± 0.1 | **627** ± 132 | **9.4** ± 0.6 |
| Mango 'Dodo' cabinet, 51 hours | **13.1** ± 4.7 | **701** ± 140 | **5.0** ± 1.0 |
| Mango 'Dodo' tunnel, 5 days | **10.4** ± 1.3 | **684** ± 91 | **5.0** ± 0.0 |
| Mango 'Kaitt' cabinet, 27 hours | **14.8** ± 0.8 | **341** ± 13 | **6.8** ± 3.0 |
| Mango 'Kaitt' cabinet, 51 hours | **7.7** ± 0.3 | **478** ± 3 | **11.2** ± 0.2 |
| Mango 'Kent' tunnel, 5 days | **13.9** ± 4.5 | **411** ± 80 | **4.5** ± 0.5 |
| Pineapple, cabinet, 51 hours | **18.0** ± 0.4 | **424** ± 15 | **13.4** ± 0.1 |
| Pineapple, tunnel, 51 hours | **30.3** ± 0.6 | **651** ± 69 | **4.2** ± 0.5 |
| Banana, cabinet, 51 hours | **30.8** ± 7.4 | **687** ± 8 | **13.5** ± 1.5 |
| Banana, tunnel, 4 days | **16.3** ± 0.8 | **612** ± 22 | **5.5** ± 0.6 |

The results were compared with the numbers from the Norwegian "Matvaretabellen" and the Tanzanian "Food composition table". All the values were calculated to mg mineral per 100 g dry matter. The results are shown in figure 4.14.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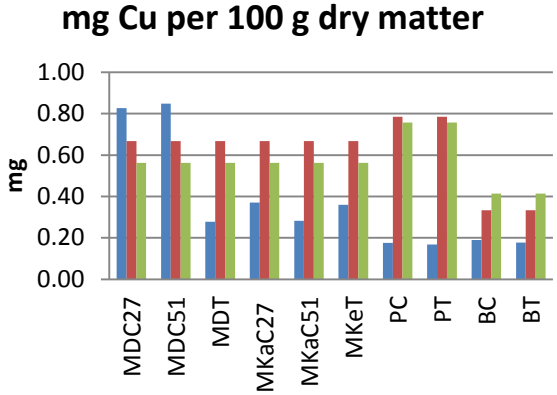
MKaC27
MKaC51
MKeT
PC
PT
BC
BT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MDT
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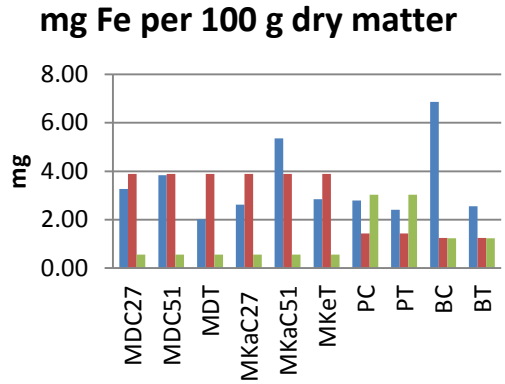
MKaC51
MKeT
PC
PT
BC
BT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PC
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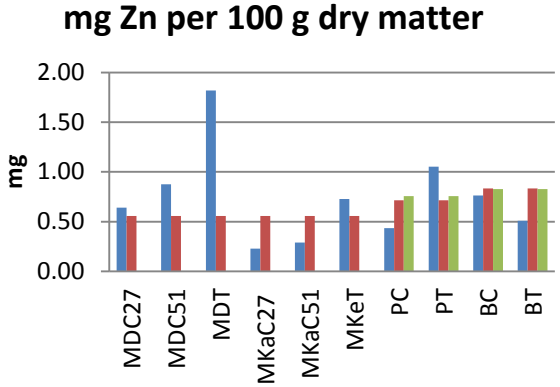
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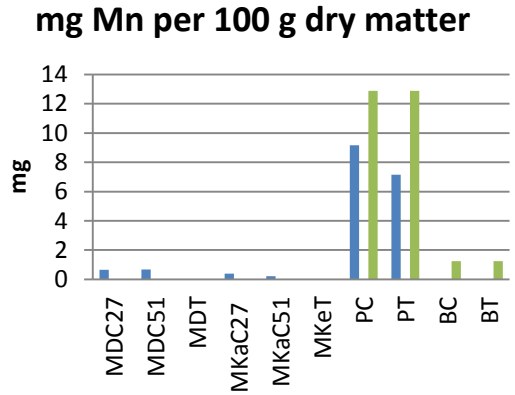
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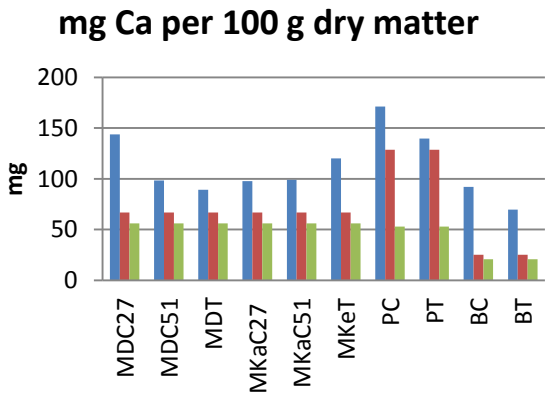
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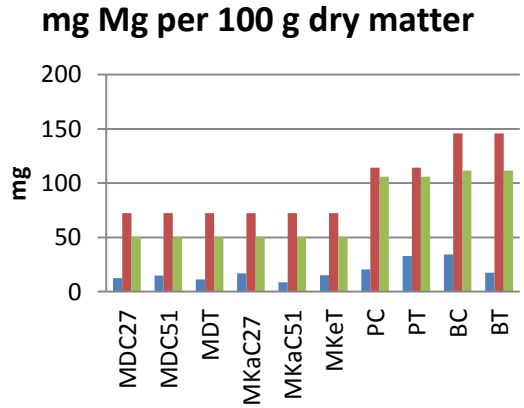
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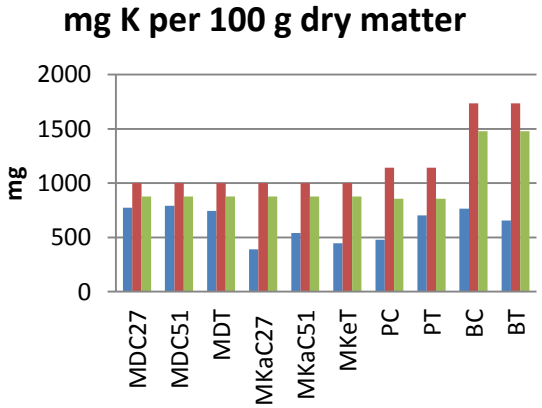
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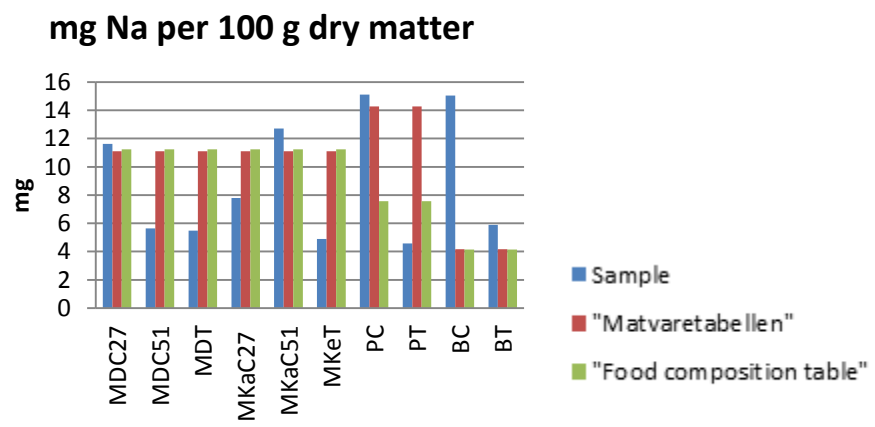



**Figure 4. 14 The mineral content in mg per 100 g dry matter in the different samples. The blue columns are the produced samples, the red columns are calculated from the Norwegian "Matvaretabellen" (Matvaretabellen.no 2006) and the green columns are calculated from the Tanzanian "Food composition table" (Lukmanji et al. 2008). The Mn content was not given in the Norwegian "Matvaretabellen".**

The results show that the standard deviations were big for many of the samples, the parallels were not good. Samples from the same variety had big variations.

### 4.3.4 Vitamin C

The first vitamin C analysis was conducted in Tanzania with spectrophotometric analysis, while the second was conducted in Norway with HPLC. The experiments in Tanzania were not successful. The procedure was followed, but the results gave no linear standard curve and the results had big standard variations.

The results from the HPLC, given in mg L-AA per 100 g sample, are shown in figure 4.8. The analysis was not done in duplicate. For comparison the numbers from the Norwegian "Matvaretabellen" and the Tanzanian "Food composition table", were used. All the values were calculated to mg L-AA per 100 g dry matter. The results are shown in figure 4.15. The correlations between the parameters are shown in table 4.9. The results came as peaks from the HPLC-machine, the result for Mango 'Kaitt' cabinet, 51 hours is showed in Appendix 3.

**Table 4. 8 The vitamin C content in the dried fruit samples, given in mg L-AA per 100 g sample.**

| Sample | mg L-AA per 100 g sample |
|---|---|
| Mango 'Dodo' cabinet, 27 hours | 65.0 |
| Mango 'Dodo' cabinet, 51 hours | 68.2 |
| Mango 'Dodo' tunnel, 5 days | 41.0 |
| Mango 'Kaitt' cabinet, 27 hours | 113,4 |
| Mango 'Kaitt' cabinet, 51 hours | 101,6 |
| Mango 'Kent' tunnel, 5 days | 42.5 |
| Pineapple, cabinet, 51 hours | 16.8 |
| Pineapple, tunnel, 51 hours | 5.8 |

| Sample | mg L-AA per 100 g sample |
|---|---|
| Banana, cabinet, 51 hours | 5.8 |
| Banana, tunnel, 4 days | 3.5 |

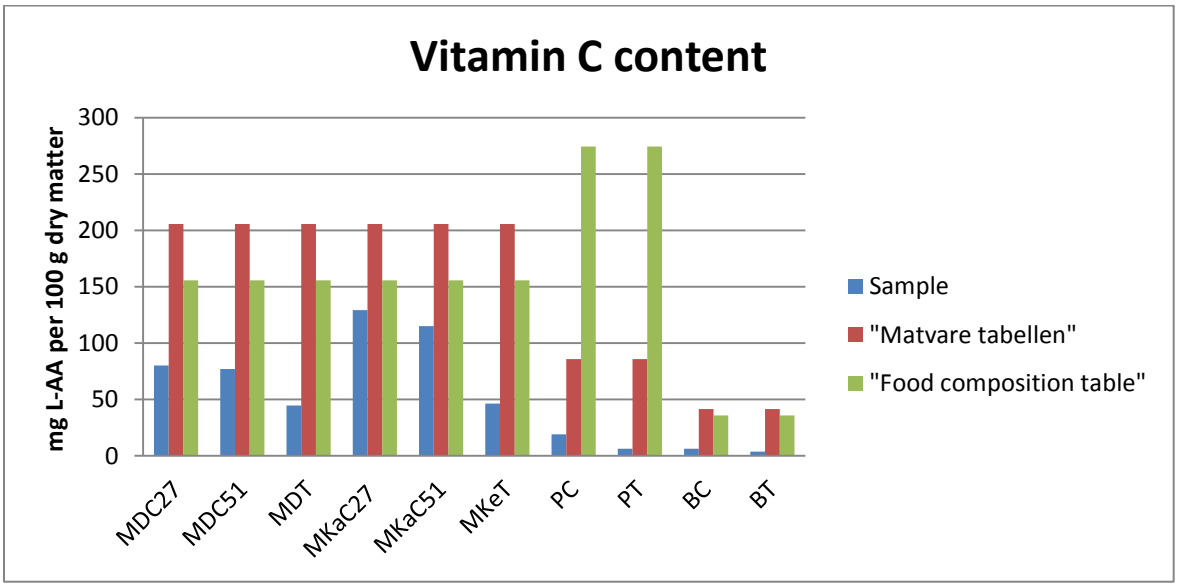



**Figure 4. 15 The vitamin C content in mg per 100 g dry matter in the samples. The blue columns are the produced samples, the red columns are calculated from the Norwegian "Matvaretabellen" (Matvaretabellen.no 2006) and the green columns are calculated from the Tanzanian "Food composition table" (Lukmanji et al. 2008).**

**Table 4. 9 The correlations between the parameters in the vitamin C analysis, where the upper values are the Pearson correlations, and the second values are the P-Values. . Time is drying time, 27 hours, 54 hours, 4 days and 5 days and drying method is cabinet or tunnel dryer.**

| | Fruit variety | Time | Drying method | mg L-AA per 100 g sample |
|---|---|---|---|---|
| mg L-AA per 100 g sample | -0.772<br>0.009 | -0.518<br>0.125 | -0.498<br>0.143 | |
| mg L-AA per 100 grams dry matter | -0.775<br>0.008 | -0.549<br>0.100 | -0.516<br>0.127 | 0.999<br>0.000 |

The results show correlation between fruits and vitamin C content. Longer drying time and lower moisture content gave lower vitamin C content, but this was not significant. All the results were lower than the ones calculated from the food tables.

## 4.4 Sensory evaluation

Different sensory evaluations were conducted; one focus group interview and two sensory product tests, one in Tanzania and one in Norway.

### 4.4.1 Focus group

The focus group was conducted with eight Tanzanian students. Some of the participants had tasted dries fruits or vegetables before. They had eaten dried cassava, sweet potato, mango, banana, orange and raisin. They liked what they had eaten, but did not eat it on a regular

basis. All were positive to taste the dried fruits. They tested the dried fruits without knowing which variety they tasted, or the differences between the samples. They first tasted the three 'Dodo' samples, one at a time. Most of them found the sample dried 51 hour in the cabinet dryer the best. The sample had a good taste, and enough taste. They then tasted the 'Kaitt' and 'Kent' samples. Most of them found the sample dried 51 hour in the cabinet dryer the best. It had the best taste and a good texture. Among the pineapples, most of them preferred the sample from the tunnel. The sample was drier and not as sticky as the one from the cabinet dryer. Among the bananas there were no clear favourite. Some of them liked both the samples, but some thought they were too sweet and not had the taste of banana. In the end they were asked about overall liking. Six of the participants preferred mango and two of them preferred pineapples. Sayings about all the samples are in appendix 4.

### 4.4.2 Consumer test

After the focus group interview, seven samples to use in the consumer test were chosen. The consumers were asked about four characteristics and liking. In Tanzania 104 people participated in the consumer test, but nine questionnaires were rejected because of incorrect or not completed filling. In Norway 98 people participated in the consumer test, one questionnaire was rejected because of not completed filling.

The Norwegian and the Tanzanian consumers mean liking of the products, with standard deviations, are shown in figure 4.16. The consumers were asked about their interest in buying the products, excluding price as a matter, the results are shown in table 4.10.

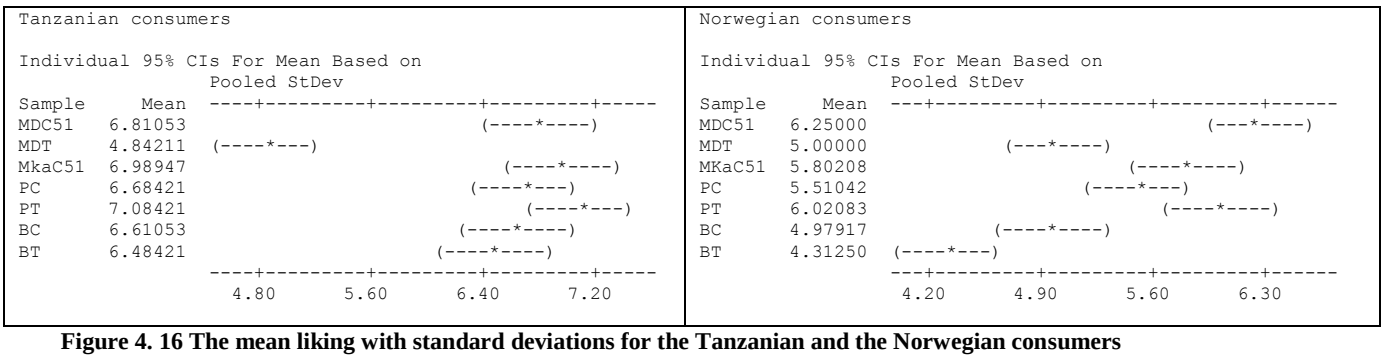



**Figure 4. 16 The mean liking with standard deviations for the Tanzanian and the Norwegian consumers**

**Table 4. 10 The percentage of the Norwegian and Tanzanian consumers' interest in buying the products**

| Sample | Interest in buying | |
|---|---|---|
| | Tanzania | Norway |
| Mango 'Dodo' cabinet, 51 hours | 81 % | 67 % |
| Mango 'Dodo' tunnel, 5 days | 42 % | 36 % |
| Mango 'Kaitt' cabinet, 51 hours | 83 % | 58 % |
| Pineapple, cabinet, 2 days | 79 % | 48 % |
| Pineapple, tunnel, 2 days | 77 % | 57 % |
| Banana, cabinet, 51 hour | 77 % | 36 % |
| Banana, tunnel, 4 days | 73 % | 24 % |

The results show that the Tanzanian consumers had a higher overall liking of the product, and no significant difference in the liking of the fruit, except the Mango 'Dodo' tunnel sample. The Norwegian consumers had a lower overall liking, and differentiated more between the samples. The consumers had a significant difference in liking among several of the samples. The Tanzanian consumers were more interested in buying the products.

Product characteristics were made with help of the questions about the characteristics. One was made with the meanings of the Tanzanian consumers, one with the Norwegian consumers and one with both the Tanzanian and Norwegian consumers. The preference mapping plots with the correlation loadings are showed in figures 4.17, 4.18 and 4.19. The plots show which characteristics the products had and the mean liking of the consumers. The products are written in green, the characteristics are written in blue and the mean likings are written in red.

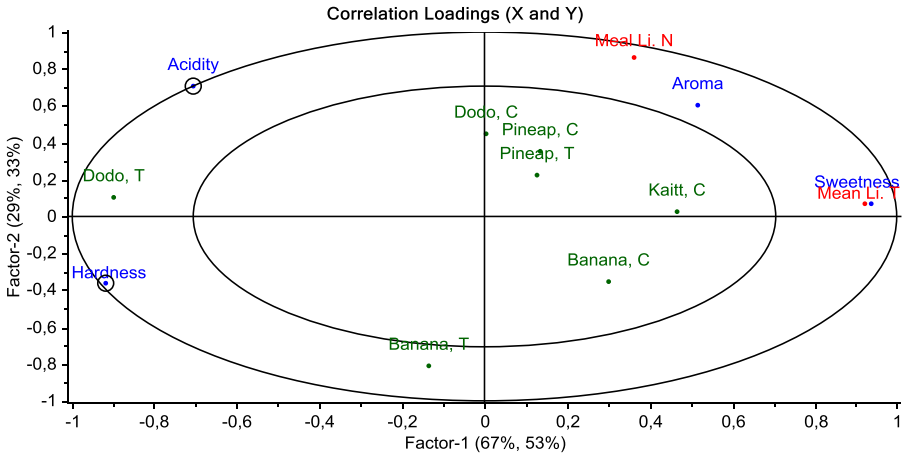



**Figure 4. 17 Product characteristics with the mean of the Tanzanian and Norwegian consumers' meanings and the mean liking for the consumers from both countries.**

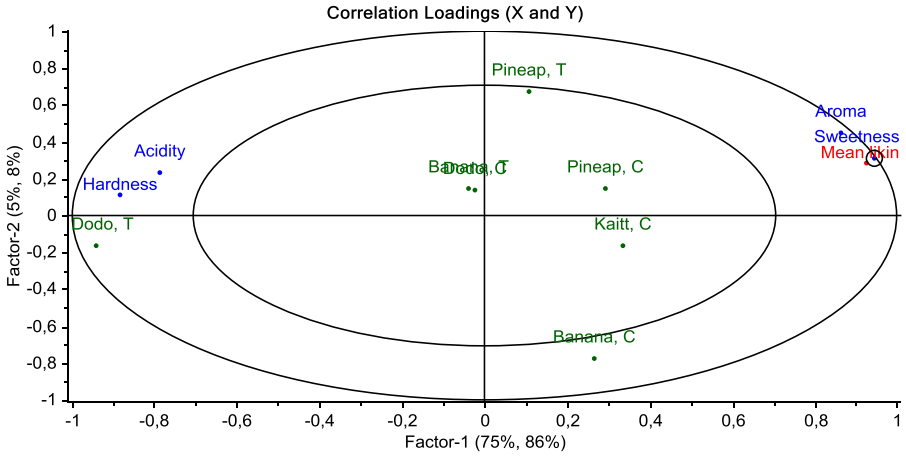



**Figure 4. 18 Product characteristics with the Tanzanian consumer's meanings and the mean liking for the Tanzanian consumers.**

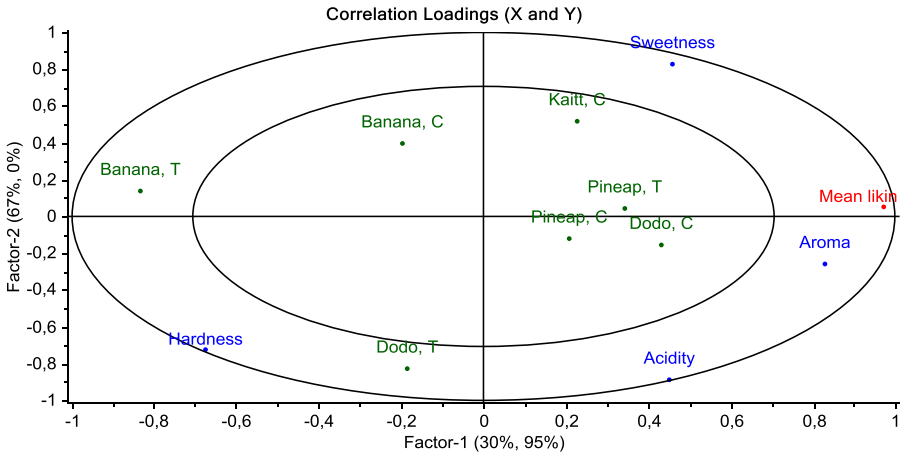



**Figure 4. 19 Product characteristics with the Norwegian consumers' meanings and the mean liking for the Norwegian consumers.**

The results show that the consumers from the different countries described the dried fruits in different ways. The Norwegian consumers differentiated more between the samples. The descriptions also have similarities. Consumers from both countries thought 'Dodo' Tunnel differed most from the rest of the samples, and was harder. The Tanzanian consumers meant that the 'Dodo' Tunnel sample was more acidic, contrary of the Norwegian consumers. The sweetness of the samples was most important for the Tanzanian liking, while the aroma was most important for the Norwegian consumers.

# 5 Discussion

## 5.1 Drying

Many factors affect solar drying. Both quality of raw material as texture, size, density and moisture content, and external factors as temperature, humidity and air flow rate have an impact on the drying (Augustus Leon et al. 2002). The product factors are possible to control to a certain point by choosing raw material with good and equal quality. The external factors are not controllable; the weather changes and affects the drying conditions. To make a drying procedure with a certain time is hard; two days of drying are not the same in warm and dry weather and in cloudy and rainy weather.

In this experiment one of the goals was to compare the cabinet dryers and the tunnel dryer. Augustus Leon et al. (2002) have in the article "A comprehensive procedure for performance evaluation of solar food dryers", presented different ways of evaluating solar dryers. They have made a list of the parameters which should be evaluated, including the physical features of the dryer, the thermal performance, the quality of the dried products and the economics. In this master thesis all these parameters were not included. Grupp et al. performed a test where they tested six types of solar dryers. The tunnel dryer scored highest in overall performance in this test (Grupp et al. 1995).

For comparing the drying in the cabinet dryers and the tunnel dryer, it should have been the same conditions during the dryings. During the drying of mango and banana in the tunnel dryer it was raining. These samples had to be dried for a longer time than the samples from the cabinet dryer; hence they did not have the same conditions. The pineapple samples were dried equally long in the tunnel dryer and the cabinet dryer, and the weather conditions were quite similar. For these samples it was possible to compare the dryers. In this experiment the tunnel dryer gave lower moisture content than the cabinet dryer for the pineapple samples.

## 5.2 Microbiology

During drying the hygiene is important for not contaminate the samples with unwanted microorganism. The fruit has naturally a peel that protects the fruit flesh from microorganisms. During the cutting the peel is removed and the flesh is exposed to the cutting equipment and the surroundings. Clean equipment and a clean processing place are important. The fruit has to be washed before processing. The water can be added a sanitizer, like chlorine, this should be added in the concentration 200-300 µg/ml. The chlorine will be ineffective if the concentration is to low and the water contains much organic material. Clean

tap water is almost as effective as water with chlorine(Sumner & Peters 1997). Experience shoved that the tap water in Tanzania was not clean, and it was necessary to use a sanitizer in the water. During the processing chlorine was used, but the amount used may have been too small.

The growth of microorganisms depends among others on the moisture and acid content in the sample. Fresh fruit has low pH, which leads to most fruit being spoiled by fungi and not bacteria. Bacteria grow in general fastest in the pH range 6.0-8.0, yeast in the range 4.5-6.0 and filamentous fungi in the range 3.5-4.0 (Adams & Moss 2008). Fresh fruit has generally pH below 4.5 (Wills et al. 2007).

The moisture content in a sample can be expressed on wet-weight basis or on dry-weight basis. Wet-weight basis is (mass of water/mass of sample)*100, while dry-weight basis is mass of water/mass of solids (Lewis 1990). Wet-weight basis is normally used in food composition tables; this is also used in this assignment. The moisture content alone says not all about the stability of the food; it is the availability of the water that is important. The availability is measured by the water activity ($a_w$), which is defined as "*the ratio of the vapour pressure of water in a food to the saturated vapour pressure at the same temperature*". $a_w$ = vapour pressure of the food (P) / vapour pressure of pure water at the same temperature ($P_0$) (Fellows 2000).

Most fungi are inhibited below $a_w$=0.7, most yeast below $a_w$=0.8 and most bacteria are inhibited below $a_w$=0.9 (Fellows 2000), but there are exceptions. Halophilic bacteria can grow down to $a_w$=0.75 and Xerophilic fungi down to $a_w$=0.61 (Adams & Moss 2008). Dried fruits with 15-20 % water have $a_w$=0.6-0.7 (Adams & Moss 2008; Fellows 2000). Properly dried fruit will have little growth of microorganism.

According to Shama et al (2008) the moisture content in banana should be below 15 % in wet-weight basis, and below 10 % in wet-weight basis for pineapples. The moisture content in the banana samples were both under 15 %, and had acceptable moisture content. The moisture content in the pineapple samples from the cabinet dryer was higher than 10 % and may as such been too high. Maximum moisture content for dried mango was not found in the literature. One of the mango samples had moisture content of almost 20 %, which was high and might cause microbiological growth.

The second attempt to conduct the microbiological analyses in Tanzania ended in growth on the petri dishes that were supposed to be sterile. The sterilization was conducted the same way as under the first microbiological analyses, where it was used embedding and no control of the agar was done. The agar and equipment may not have been properly sterilized for the first analyses either and the results may show a higher number than what was actually present. Most of the results were acceptable, but some of them had big differences among the parallels and the dilutions, this shows that it may have been contamination.

Three aspects make the microbiology of the food important, the safety, the acceptability and the consistency. The food must not contain levels of pathogens or its toxins that can cause illness during consumption. The food must not contain levels of microorganisms that spoil the food in a unacceptably short time, and the food must have the same quality from batch to batch (Adams & Moss 2008).

In fresh produce the microbiological counts vary from < log 2 cfu/ml to log 6 cfu/ml (Sumner & Peters 1997). In the samples the mesophilic growth varied from log 2 cfu/g to log 5 cfu/g for the analyses in Tanzania, and from log 2 cfu/g to log 4 cfu/g for the analyses in Norway. Most of the samples had higher growth in Tanzania than in Norway. Reasons may be not complete sterilization of the equipment or decrease of bacteria during storage. The coliform growth on Mac Conkey agar in Tanzania showed high values. Coliform bacteria are a sign of faecal contamination and should not be present on the samples. Coliform bacteria as *E.coli* may cause illness as diarrhoea (Adams & Moss 2008). In Norway less coliform bacteria was found. Reasons may be the same as for the mesophilic bacteria, to high number due to unsterile equipment or decrease of bacteria during storage. The Mac Conkey agar was incubated at 30 °C, but should have been incubated at 37 °C, which can be another source of error. Distilled water was used for the first dilution in the microbiological analyses in Tanzania; this may have given the microorganism osmotic shock.

The correlation analysis for the results in Norwegian analyses showed no correlation between the post-treatment and the growth of mesophilic bacteria or the growth of mould and yeast. Most of the samples had higher growth of both mesophilic bacteria and mould and yeast on the samples stored in freezer compared to the ones stored at room-temperature. This may be because the bacteria died on the samples at room-temperature, due to the dry surface with low $a_w$. Freezing do not inactivate enzymes and has a variable effect on microorganism. Gram-positive bacteria, mould and bacteria spores are little affected by low temperatures, while

yeast, mould and gram-negative bacteria are more easily destroyed. Food is especially exposed for microbiological growth during thawing. The surface becomes a bit rehydrated and this gives the microorganisms good growth conditions (Adams & Moss 2008). The frozen samples was thawed and refrozen several times during the storing, which gave the microorganisms chance to grow.

None of the samples had visible changes due to the microorganisms. The test for coliform bacteria in Norway showed that most of the samples did not contain these bacteria. The 'Dodo' sample dried for 27 hours in a cabinet dryer had > log 3 cfu/g coliform bacteria on the frozen sample and no growth on the sample stored at room-temperature. This can be because some parts of the sample were contaminated during the processing. The sample with high moisture content did not distinguish from the rest of the samples. The growth of mesophilic bacteria and mould and yeast were quite similar on the different samples. It was not conducted any analysis to find which mould and yeast present, or if any of them produced toxin.

The contaminated samples did not show any growth of coliform bacteria (in the Norwegian analyses), this may be because the bacteria was destroyed during the drying, or because the faeces used were dry and did not contain any coliform bacteria.

The results show no clear differences in growth on samples from the different dryers or between the different fruit varieties.

The analyses were performed in a way that found the microorganisms on the surface of the fruit. All the results are given per g sample. It may be differences between the sizes of the surfaces of one g sample depending on the moisture content, the thickness of the fruit sample and differences from the preparation of the samples. In Tanzania two different preparation methods were used, and in Norway yet another. The feed trial in Norway showed that the three methods used gave quite similar results; hence it is reason to believe that the preparation did not have a big impact on the result.

## 5.3 Hazard analysis and Critical Control Points

When making a process procedure a hazard analysis should be conducted to find the critical control points; the points in the process where the possible hazards are. The points should be possible to control and limits should be made for the process at these points. The limits can be physical parameters as temperature and humidity, chemical parameters as pH and $a_w$, sensory

information as texture and management factors as correct labelling (Adams & Moss 2008; Fellows 2000).

The drying process has many hazards; some of them are not easy to control. The raw-material is the first hazard; it must have a good quality. It must be fresh and mature, not started too rotten or contain worms; the sensory information is the control. The cutting is the next hazard, the equipment and the environment must be clean. During the drying the $a_w$ in the fruit must be decreased to a safe level. The dried fruit should be tested microbiological to control the microbiological growth.

## 5.4 Nutrition and chemical changes

During the drying, the nutrient content in the fruit change. Many of the changes happen during the preparation and not in the actually drying. Esher and Neukom did a study of drum-drying of apples in 1970 and showed that 8 % of the vitamin C loss happened during slicing, 62 % during blanching, 10 % during pureeing and 5 % during drum drying (Escher & Neukom 1970). In apples, apricots, peaches and prunes the vitamin C losses were around 56 % during the drying process, whereas the vitamin $B_2$ losses were close to 0 %. The losses of the nutrients depend on the nutrients properties. The water-soluble vitamins Thiamine and Vitamin C are heat- and oxidation sensitive, and the loss can be over 50 % during drying. The other water-soluble vitamins, as $B_2$, are more heat- and oxidation stable and the losses during drying are usually 5-10 %. The fat-soluble vitamins are less affected by drying because they are present in the dry matter of the fruit. Losses of water lead to higher oxidation and vitamins can be lost due to fat oxidation. The vitamin A loss in apple, apricot, peach and prune was around 6 %, while the protein value changed little during drying (Fellows 2000). Vitamin A losses in dried fruit are quite low, as such dried mangoes are a good source for vitamin A. Rankins et al. suggest that dried mango should be included in the diet in West-Africa when mangoes are not in season. That would lead to diet diversity, adding vitamin A to the diet where vitamin A deficiency is widespread and it would reduce the post-harvest losses (Rankins et al. 2008). Reduction in the sugar content in dried fruit indicates high temperature during drying and lowers the quality of the product. An increase in the acidity indicates fermentation and thereby quality deterioration (Augustus Leon et al. 2002).

### 5.4.1 Protein

The protein content in 100 g dry matter should be the same in the samples from the same variety. This was not reality. For the banana samples the values were quite similar, but the

other had differences between the samples from the same variety, and they varied from the values in the "Matvaretabellen" and the "Food composition table". The biggest differences were among the mango 'Dodo' samples. Reasons for the variations may be due to bad homogenization of the samples before analysing or wrongly performed analysis. The values were calculated from the measured moisture content. The moisture content may have varied in the samples, and the parts used in the protein analysis and the moisture analysis may have had different moisture content. The value from the second analysis performed on the 'Dodo' sample dried for 27 hours in a cabinet dryer was much lower than the value from the first analysis; ca. 15 g per 100 g dry matter was found in the first analysis, whereas ca. 3 g per 100 g dry matter was found during the second analysis. The new value was lower than most of the other mango-samples, and might be a sign that the other values were too high. The standard deviations were low.

### 5.4.2 Vitamin C

The spectrophotometric analysis of vitamin C gave no good results. This might be due to difficulties following the procedure.

The results from the HPLC analysis showed big variation among the different samples. It was significant difference between the fruit varieties, where 'Kaitt' mango had the highest content followed by 'Dodo' mango. The results showed that longer drying time gave lower vitamin C content, and that the samples from the tunnel dryer had lower vitamin C content than the samples from the cabinet dryer. These differences were not significant; that may be due to too little analysis material. All the samples had lower values than the values calculated from the food tables. Vitamin C is sensitive to heat and oxidation. The content will decrease during cutting and drying. Low drying temperature and short drying time will be most gentle on the vitamin C content (Damodaran et al. 2008; Fellows 2000).

### 5.4.3 Minerals

Minerals are stable, and cannot be destroyed by exposure to heat, light, oxidizing agents or extremes in pH. The mineral content is similar to the ash content and is found by burning the sample. The ash remaining after burning can be analysed for the different minerals (Damodaran et al. 2008). The ash contents in the samples should be quite similar to the calculated values and the variation in mineral content in the dry matter among the samples from the same variety should be minimal.

Phosphate (P) is present in virtually all foods, and deficiency is rare. Fresh fruit contains around 10-20 mg per 100 g. Many foods contain Copper (Cu) and deficiency is rare. Fresh fruit contains around 0.1 mg per 100 gr. Iron deficiency will lead to anaemia. Cereals and meat are important sources of iron (Fe) while the content in fruit is low, around 0.5 mg per 100 g. Zinc (Zn) is present in meat and cereals, whereas the content in fruit is low, around 0.1 mg per 100 g. Zinc deficiency will lead to loss of appetite, growth retardation and skin changes (Fellows 2000; Matvaretabellen.no 2006). Whole grains, fruits and vegetables contain Manganese (Mn), deficiency is rare (Fellows 2000). The content in fresh fruit varies from 0 g in mango and 0.3 mg per 100 g banana to 1.7 mg per 100 g in pineapple (Lukmanji et al. 2008). Calcium (Ca) is present in dairy products and green leafy vegetables, and is important to prevent osteoporosis. The content in fresh fruit is quite low, around 10 mg per 100 g. Whole grains, nuts and legumes contain Magnesium (Mg) and deficiency is rare. Fresh fruit contains around 15-30 mg per 100 g. Potassium (K) is present in fruits, vegetables and meat; deficiency is rare. Mango and pineapple contain around 160 mg per 100 g, while banana contain over 400 mg per 100 g. Sodium (Na) is used as a food additive and most raw foods contain little sodium; deficiency is rare. Fresh fruit contain around 1 mg per 100 g (Fellows 2000; Matvaretabellen.no 2006).

Most of the dried fruits had lower mineral values than the values from the tables. Samples from the same variety had big variations, and the results had no system. The variation may be a sign that the samples were bad homogenized or that the analysis was wrongly performed. The burning in the Muffle furnace was not complete; much carbon remained in the samples. The minerals may have been attached to the carbon and not able to dissolve in the HCl added. The samples should have been burned once more. All the results had big standard deviations, so the results may be too high or low. The dried fruits were not especially rich in any particular minerals, but they can contribute with some minerals in a varied diet.

### 5.4.4 Volatile compounds

Drying effects the volatile compounds of the fruit, which lead to less flavour and aroma in the dried fruit. High temperature during drying leads to increased loss of volatiles. Oxidation of volatiles and fat during storage has also an impact on the flavour. Oxidation of unsaturated fatty acids may lead to unwanted odour. Sulphur dioxide, ascorbic acid and citric acid can be used to prevent changes in the flavour due to oxidative and hydrolytic enzymes. The enzyme glucose oxidase, can be used to protect dried food from oxidation during storage by placing the enzyme inside the storage container to remove oxygen (Fellows 2000).

### 5.4.5 Browning

Drying may cause browning of the fruit. The products may turn brown because of enzymatic or non-enzymatic browning. Enzymatic browning is browning catalysed by enzymes, and is common in freshly cut fruits. Non-enzymatic browning can be divided in Maillard reactions and caramelization. A Maillard reaction is a reaction between a reducing sugar and a primary amino group during heating. The reaction is dependent on the temperature, the time, the pH and the water activity. High temperature and high pH increase the reaction, maximum reaction occurs at $a_w$=0.6-0.7. A caramelization happens during heating of carbohydrates, in particular sucrose and reducing sugars. The reaction occurs without nitrogen-containing compounds, but is otherwise quite similar to the Maillard reaction. Both the reactions give a mixture of polymeric compounds, different flavours and aromas and brown-coloured polymers. The Maillard reaction can also give acrylamide, which is an unwanted compound as it may cause cancer. The non-enzymatic browning processes may be desired or undesired. During baking and roasting the volatile compounds and the brown colour is wanted, while in other processes the brown colour is not wanted (Damodaran et al. 2008).

During the drying of mangos in the tunnel, the samples got brown spots. Enzymatic browning usually occurs in freshly cut fruit, and as the samples dried in the cabinet dryers not got brown spots, it is reason to believe that non-enzymatic browning caused the spots. Whether it was a Maillard reaction or a caramelization is difficult do decide. Mango contains much carbohydrate and only small amounts of protein (Matvaretabellen.no 2006), as such, it is possible that only the sugars reacted and that it was a caramelization. Reasons for the reaction may have been warm weather combined with high humidity.

## 5.5 Sensory evaluation

In a focus group the participants should not know each other and not have any knowledge about the product (Lawlwss & Haymann 1999). In this study many of the participants knew each other, and some of them were food science students; which not were the optimal conditions. The participants liked the mango samples dried for 51 hours the best. These samples had the best taste and the best texture. The mango samples dried for 27 hours were too soft and the ones from the tunnel were too dry. Most of them did not like the samples from the tunnel dryer which correlated with the poor weather conditions during drying, and the samples not having the desired quality. Some of the participants liked the mango samples from the tunnel dryer and said it had a nut and caramel-like flavour. The participants liked the pineapple from the cabinet best. The samples had lower moisture content and were not as

sticky as the ones from the tunnel. The banana sample from the tunnel dryer had, like the mango samples, not the desired quality, but the consumers in the focus test did not distinguish it from the sample from the cabinet dryer. The results from the focus group interview were used to choose seven samples for the consumer test.

The same consumer test was conducted in Norway and Tanzania to see how the consumers liked the products, if they were interested in buying the products and possible differences between the Norwegian and Tanzanian consumers. The results show that the Tanzanian consumers had a higher liking of the products than the Norwegian consumers, and they were more interested in buying the products. The Norwegian consumers differentiated more between the products. The Norwegian consumers had eaten more dried fruits and may be used to a bigger variety in the diet.

The product characteristics showed some differences between the Norwegian and the Tanzanian consumers' opinions of the product samples and the liking. For the Norwegian consumers the aroma of the product was most important, while for the Tanzanian consumers the sweetness of the sample was most important. The Norwegian consumers liked the 'Dodo' and 'Kaitt' mango samples dried for 51 hours in the cabinet dryers and the pineapple dried in the tunnel dryer best, and were most interested in buying these samples. The Tanzanian consumers liked all the samples they tasted the same except the mango sample from the tunnel dryer. The consumers did not taste the mango samples dried for 27 hours in the cabinet dryers or the 'Kent' sample from the tunnel dryer. The results show that it may be a marked for both dried mangos and pineapple in Norway. The samples should not be as humid that they are sticky, but not as dry that they are hard. The samples should be sweet, acidic and have a good aroma. The banana was not that popular, but may be used in nut- or cereal mixtures.

In the consumer test the consumers were asked about the characteristics of the product before the overall liking. The consumers should have been asked about the liking before the characteristics and for a better results of the characteristics the test should be performed by a trained panel (Lawlwss & Haymann 1999).

## 5.6 Drying factors

The weather is a non-controllable factor. Solar drying is depending on sun, but the temperature in the dryer should not be too high. Bananas can maximum have a temperature of 70 °C and pineapple can maximum have a temperature of 65 °C (Sharma et al. 2008). To high

temperature may lead to browning of the products. The temperature in the dryers during the drying was not measured. By using temperature loggers during the drying it would have been possible to see how the temperature affected the drying.

The three factors air temperature; air humidity and air velocity affect the airs capacity to remove moisture. The temperature affects how high moisture content the air can have before it is saturated. Air at high temperature can have higher humidity than air at lower temperatures. Air with high humidity cannot absorb much vapour, and makes it harder for the water in the sample to vaporise. By having high air velocity the vapour is removed faster, and the new air will be ready for absorption of new moisture (Fellows 2000).

The cabinet dryer had natural air circulation, while the tunnel dryer had a fan that gave higher air velocity, which should lead to better drying conditions. The air humidity and velocity were not measured during the drying. By measuring this it would have been possible to see how these parameters affected the drying.

## 5.7 Challenges

Working in Tanzania provided many challenges; some that had impact on the processing of the food, and some that had impact on the analysing. Water, electricity and equipment were some of the challenges. The tap water was not clean and sometimes it was limitations in the supply. These elements led to problems with cleaning of the fruits and the equipment. To counteract the unclean water some chlorine was added, but the chlorine was added in small amounts and it did not remove the sand in the water. During shortage in the water supply, the water had to be transported to the processing place, witch lead to delays in the processing. There were many power breaks during the work in Tanzania. Three-five times a week the power was out half the day, which led to problems at the lab. The power could disappear in the middle of an analysis and the work had to be finished the next day when the power was back. The power brakes also affected the temperature in the incubator and the freezer. The varying temperature could affect the samples and the results of the analyses.

The labs used had most of the equipment for chemical analyses, but microbiological analyses were more challenging. Sterilisation of the equipment was the biggest challenge. All the glassware had to be washed, dried and sterilised in a pressure boiler. During the sterilisation it was discovered that the pressure boiler leaked, and the temperature did not reach 121 °C. The lab had no small bottles for the agar, and the agar had to be made in big bottles, which made it difficult to sterilise and keep liquid during pouring. Some of the chemical analyses were

performed by the lab technicians at other departments, which made it hard to know exactly what they were doing during the analyses.

## 5.8 Storing and packaging

The samples were frozen during storage. According to the project managers in Tanzania, freezing the samples were the procedure for dried fruit in Uganda to kill living organisms, like flies and their eggs. The results showed that the level of microorganisms was higher in the frozen samples; this may be due to rehydration of the surface during thawing which gave good conditions for the microorganisms. It might be a good idea to freeze the samples after drying, but only for a short time to kill possible bugs, like flies, and then thaw the samples in controlled environment where the surface is quickly dried. The samples should be packed in suitable packages., in the right sizes and material and with the right gasses(Fellows 2000). For distribution in Tanzania, the distribution process should be quite fast, and the packaging is not that important. For exportation to other countries the process will take longer time, and the packaging is thus more important.

## 5.9 The NUFU project

The NUFU project's goal is to make a good drying procedure that can be used by the women in the small villages. The products should have good microbiological quality, maintain the nutrition value and be accepted by the consumers. For the women in the villages the drying will be something to do between their other duties. Drying using a cabinet dryer will be most appropriate. It is cheap, does not take much room and is easy to operate and maintain. If they want to dry fruit for exportation, they must follow international regulations. The safety of the product is even more important than for sale in Tanzania, and the products should have the same variety from batch to batch.

# 6 Conclusion

The aim of this master thesis was to dry fruits using two types of solar driers and to study changes in composition of the fruits during the process. The drying and parts of the analyses were done in Tanzania; whereas the finishing analyses were done in Norway.

One of the studies was varying drying time were mangoes in the cabinet dryers were used. The result showed that longer drying time gave lower moisture content and lower content of vitamin C. The samples dried for 27 hours contained too much moisture to be regarded as safe. The consumers in the focus group preferred the samples dried for 51 hours.

The weather conditions had high impact on the drying; during bad weather conditions drying was no good and resulted in products with reduced quality.

Cabinet dryers and a tunnel dryer were used for the drying. Only pineapple had the same weather conditions in the two dryers, and the moisture content was lowest in the samples from the tunnel dryer. Experience showed that drying in cabinet dryers was the easiest and most suitable for small amounts.

The microbiological control showed that the dried samples not contained very high amounts of bacteria, moulds or yeast, but they were present. The samples stored at room temperature had higher microbiological growth than the samples stored in the freezer. The samples should be thawed in a way where the surface dried quickly or not be frozen at all.

The results from the chemical analyses showed that the vitamin C content decreased during drying, as longer drying time resulted in lower content of vitamin C. The protein and the mineral content should not be reduced during drying, however the results showed big variations in the contents. This was probably a sign of errors during the analyses. For better results more analyses should have been performed.

The consumer tests showed that the consumers preferred the mango and pineapple samples. The fruit should have right moisture content, not be too soft and not too crispy.

Drying takes long time, and during two months in Tanzania limited work could be done. Preparation of the samples for drying and preparation for the lab analyses took time, and if something went wrong during drying or analysing, it was not time to do it all over. Hence, some of the samples and results did not have the desired quality.

## 6.1 Further work

For better results more drying and analyses can be performed. For comparison of the dryers, pineapples and bananas can be dried in the tunnel dryer with good weather conditions which will give samples dried during more similar weather conditions and they will be possible to compare.

More analyses can be carried out to see the nutrition changes. Fresh fruit are rich in vitamin A, and it could be interesting to see the changes during drying. Acid and sugar analyses can be performed to see differences in the samples' taste.

It could be smart to focus on one fruit at the time. By doing this, it will be possible to use several different drying times, do more analyses and maybe find the drying method that gives the best nutrition value.

# 7. References


Adams, M., A. & Moss, M., O. (2008). *Food Microbiology*. Third ed. Guildford, UK: RSCPublishing.

Augustus Leon, M., Kumar, S. & Bhattacharya, S. C. (2002). A comprehensive procedure for performance evaluation of solar food dryers. *Renewable and Sustainable Energy Reviews*, 6 (4): 367-393.

Belessiotis, V. & Delyannis, E. (2009). Solar drying. *Solar Energy*, In Press, Corrected Proof.

Clark, J. (2000). *chemguide HIGH PERFORMANCE LIQUID CHROMATOGRAPHY - HPLC*. UK. Available at: http://www.chemguide.co.uk/analysis/chromatography/hplc.html#top (accessed: 16.06.2011).

Dachman, T., Blocker, D. E. & Baker, N. (1996). *Laboratory Manual for Human Nutrition*. New York: harwood academic publisher.

Damodaran, S., Parkin, K., L. & Fennema, O., R. (eds). (2008). *Fennema's Food Chemistry*. fourth ed. Boca Raton: CRP Press.

Earle, M., Earle, R. & Anderson, A. (2001). *Food product development*. Cambridge, UK: Woodhead Publishing Limited.

Escher, F. & Neukom, H. (1970). Studies on drum-drying apple flakes. *Trav.Chim. Aliment*, 61: 339-348.

FAO. (2003). Food energy - methods of analysis and conversion factors. Rome: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

FAOSTAT. (2011). *FAOSTAT*: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Available at: http://faostat.fao.org/site/291/default.aspx (accessed: 20.06.2011).

Fellows, P. J. (2000). *Food processing technology Principles and practice*. Cambride, UK: Woodhead Publishing Ltd.

frukt.no. (2011a). *Frukt.no Opplysningskontoret for frukt og grønt, leksikon, ananas*. Oslo, Norway: Opplysningskontoret for frukt og grønt. Available at: http://www.frukt.no/leksikon/frukt/ananas/ (accessed: 20.06.2011).

frukt.no. (2011b). *Frukt.no Opplysningskontoret for frukt og grønt, leksikon, banan*. Oslo, Norway: Opplysningskontoret for frukt og grønt Available at: http://www.frukt.no/leksikon/frukt/faktaark/banan/ (accessed: 20.06.2011).

frukt.no. (2011c). *Frukt.no Opplysningskontoret for frukt og grønt, leksikon, mango*. Oslo, Norway: Opplysningskontoret for frukt og grønt Available at: http://www.frukt.no/leksikon/frukt/mango/ (accessed: 20.06.2011).

Grupp, M., Bergler, H., Owen-Jones, M. & Schroder, G. (1995). Comparative tests of solar dryers. Technology Demonstration Center (TDC). Plataforma Solar de Almeria (PSA), Spain.

helsedirektoratet.no. (2005). *NORSKE ANBEFALINGER FOR ERNÆRING OG FYSISK AKTIVITET*. Oslo, Norway: Sosial og helsedirektoratet. Available at: http://www.helsedirektoratet.no/vp/multimedia/archive/00002/IS-1219_2606a.pdf (accessed: 20.06.2011).

Higdon, J. & Drake, V. J. (2007). *Micronutrient Information Center, Vitamin A*. Oregon USA: Oregon State University. Available at: http://lpi.oregonstate.edu/infocenter/vitamins/vitaminA/ (accessed: 20.06.2011).

Higdon, J. & Drake, V. J. (2009). *Micronutrient Information Center, Vitamin C*. Oregon, USA: Oregon State University. Available at: http://lpi.oregonstate.edu/infocenter/vitamins/vitaminC/ (accessed: 20.06.2011).

Ibarz, A. & Baebosa-Cánovas, G. V. (2003). *Unit Operations in Food Engineering*. Food preservation technology. Boca Raton, Florida: CRC PRESS.

Lawlwss, H., L. & Haymann, H. (1999). *Sensory Evaluation of food, Principles and practices*. New York, USA: KLUWER ACADEMIC/ PLENUM PUBLISHERS.

Lorenz, K., MacFarland, G. & Maga, J. (1977). Research note on pressure digestion of cereal grains and flours for mineral analysis by atomic absorption. *Cereal Chemist*, 54 (2): 281-286.

Lukmanji, Z., Hertzmark, E., Mlingi, N., Assey, V., Ndossi, G. & Fawzi, W. (2008). Tanzania food compositionTables. In Muhimbili University of Health and Allied Sciences (MUHAS), D. e. S.-T., Tanzania Food and Nutrition Centre (TFNC), D. e. S.-T. & Harvard School of Pubic Health (HSPH), B., USA (eds).

Matvaretabellen.no. (2006). *Matvaretabellen 2006*. Oslo: Mattilsynet, Helsedirektoratet, Universitetet i Oslo. Available at: www.matportalen.no/matvaretabellen (accessed: 13.07.2011).

McClements, J. (2003a). *Analysis of food produckts, Analysis of Ash and Minerals*. Massachusetts Amherst. Available at: http://www-unix.oit.umass.edu/~mcclemen/581Ash&Minerals.html (accessed: 06.07.2011).

McClements, J. (2003b). *ANALYSIS OF FOOD PRODUCTS, Analysis of Proteins*. Massachusetts Amherst. Available at: http://www-unix.oit.umass.edu/~mcclemen/581Proteins.html (accessed: 15.06.2011).

nist.gov. (2010). *Physical Measurement Laboratory, Spectrophotometry*. USA: National Institute of Standards and Technology. Available at: http://www.nist.gov/pml/div685/grp03/spectrophotometry.cfm (accessed: 20.06.2011).

NUFU. (2009). NUFU Women's Right's and Gender Equality Project document.

practicalaction.com. (2011). *Technical Information Online, Solar Drying*. Rugby, UK: Practical Action, The Schumacher Centre. Available at: http://practicalaction.org/practicalanswers/product_info.php?products_id=383 (accessed: 12.07.2011).

Rankins, J., Sathe, S. K. & Spicer, M. T. (2008). Solar Drying of Mangoes: Preservation of an Important Source of Vitamin A in French-Speaking West Africa. *Journal of the American Dietetic Association*, 108 (6): 986-990.

Sharma, A., Chen, C. R. & Vu Lan, N. (2008). Solar-energy drying systems: A review. *Renewable and Sustainable Energy Reviews*, 13 (6-7): 1185-1210.

SIU. (2011). *NUFU*: SIU. Available at: http://www.siu.no/nor/Hoeyere-utdanning-og-forskning/Samarbeid-med-utviklingsland/NUFU (accessed: 20.06.2011).

Sumner, S. S. & Peters, D. L. (eds). (1997). *Microbiology of Vegetables*. Processing Vegetables Science and Technology. Lancaster, Pennsylvania, USA: Technomic Publishing Company, Inc.

tropicalfruitnursery.com. (2011a). *Pine Island Nursery, Mango, Keitt*. Miami, Florida, USA: Pine Island Nursery. Available at: http://www.tropicalfruitnursery.com/mango/keitt-mango.shtml (accessed: 20.06.2011).

tropicalfruitnursery.com. (2011b). *Pine Island Nursery, Mango, Kent*. Miami, Florida, USA: Pine Island Nursery. Available at: http://www.tropicalfruitnursery.com/mango/kent-mango.shtml (accessed: 20.06.2011).

Van Arsdel, N. B. & Copley, M. J. (1963). *Food Dehydration*. Westport, CT: AVI.

Volden, J. (2008). *Effects of thermal processing and freezer storage on glucosinolates and antioxidant-related parameters in Brassica oleracea*. Ås, Norway: Universitetet for miljø- og biovitenskap.

Waters. (2011). *HPLC - High Performance Liquid Chromatography*. Milford, USA: Waters. Available at: http://www.waters.com/waters/nav.htm?locale=en_NO&cid=10048919 (accessed: 16.06.2011).

WHO. (2003). Diet, nutrition and the prevention of chronic diseases. 2003.

Wills, R., McGlasson, B., Graham, D. & Joyce, D. (2007). *Postharvest*. 5th ed. Wallingford: CABI.

# Appendix 1

## 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): Temu, 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.

## Informasjon

| | |
|---|---|
| **Program:** | NUFU - Women's rights and gender equality |
| **Periode:** | NUFU Women's Rights and Gender Equality |
| **Prosjekt ID:** | NUFUGe-2008/10181 |
| **Status:** | Aktiv |
| **Kategori:** | Bilateral cooperation project |
| **Tildeling:** | 2 879 000 NOK |
| **Fagområde(r):** | Economics |
| | **Food technology** |
| | Agriculture |
| | Other agricultural sciences |

# Appendix 2

Consumer test – Dried fruit

Gender

- Male
- Female

Age: _____

What is your highest education?

- No education
- Primary school
- Secondary school
- High school
- Diploma
- University

How often do you eat dried fruits?

- Newer
- once every 6th month
- one a month
- weakly

In a scale from 1 to 9, where 1 is low intensity, and 9 is high intensity, how do you find the following characteristics for the different fruits. Taste the samples in the order they are listed.

**Sample_____**

**Hardness**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not hard | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very hard |

**Sweetness**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not sweet | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very sweet |

**Acidity**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not acidic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very acidic |

**Aroma**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not aromatic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very aromatic |

**What is your total liking of the product?**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Don't like it | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Like it a lot |

**Would you be interested in buying this product?**

Yes No

**Sample_____**

**Hardness**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not hard | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very hard |

**Sweetness**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not sweet | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very sweet |

**Acidity**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not acidic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very acidic |

**Aroma**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not aromatic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very aromatic |

**What is your total liking of the product?**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Don't like it | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Like it a lot |

**Would you be interested in buying this product?**

Yes No

**Sample_____**

**Hardness**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not hard | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very hard |

**Sweetness**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not sweet | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very sweet |

**Acidity**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not acidic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very acidic |

**Aroma**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Not aromatic | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Very aromatic |

**What is your total liking of the product?**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Don't like it | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Like it a lot |

**Would you be interested in buying this product?**

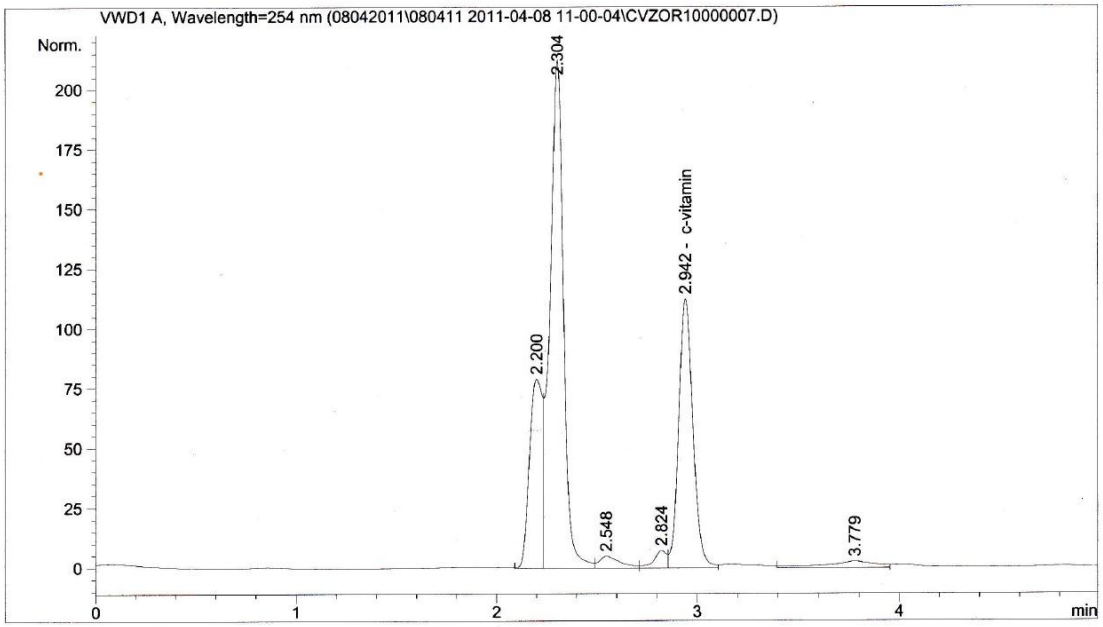
Yes No

# Appendix 3

Result direct from HPLC for Mango 'Kaitt' cabinet, 51 hours.

```
Data File C:\CHEM32\1\DATA\08042011\080411 2011-04-08 11-00-04\CVZOR10000007.D
Sample Name: Mango

==========================================================================
Acq. Operator   : ks                              Seq. Line :   6
Acq. Instrument : Instrument 1                    Location : Vial 6
Injection Date  : 4/8/2011 11:36:26 AM                 Inj :   1
                                                 Inj Volume : 5 µl
Acq. Method     : C:\Chem32\1\DATA\08042011\080411 2011-04-08 11-00-04\CVZOR10.M
Last changed    : 10/26/2010 3:11:07 PM by ks
Analysis Method : C:\CHEM32\1\METHODS\CVZOR10.M
Last changed    : 4/8/2011 11:37:05 AM by ks
                  (modified after loading)
Method Info     : Analyse av l-ascorbinsyre
                  Gammel Zorbax 2001
                  Ny standardkurve 21,06,2010
```




```
==========================================================================
          External Standard Report (Sample Amount is 0!)
==========================================================================

Sorted By             :      Signal
Calib. Data Modified  :      4/8/2011 11:37:04 AM
Multiplier            :      1.0000
Dilution              :      1.0000
Do not use Multiplier & Dilution Factor with ISTDs

Signal 1: VWD1 A, Wavelength=254 nm

RetTime  Type     Area      Amt/Area    Amount   Grp   Name
 [min]          mAU   *s              [mg/100 g]
-------|------|----------|----------|----------|--|------------------
  2.942 VV      550.30890 1.84703e-2   10.16439    c-vitamin

Totals :                               10.16439


==========================================================================
                          *** End of Report ***

Instrument 1 4/8/2011 11:48:29 AM ks                    Page   1 of 1
```

## Appendix 4

Sayings about the dried fruit in the focus group interview, the samples are listed in the order they tested them.

| **Sample** | **Opinion** |
|---|---|
| Mango 'Dodo' cabinet dryer,51 hours | Good<br>Enough taste |
| Mango 'Dodo' Tunnel dryer | To dry<br>More sour<br>Nut and caramel-like flavour |
| Mango 'Dodo' Cabinet dryer, 27 hours | Softer<br>Sweeter<br>Fibers |
| Mango 'Kaitt' Cabinet dryer, 27 hours | Texture: nice, perfect<br>To sweet taste |
| Mango 'Kent' Tunnel dryer | To dry<br>Good texture<br>Not so acidic<br>To sweet |
| Mango 'Kaitt' cabinet dryer,51 hours | Good flavor<br>Good texture<br>Nice aroma<br>Sticky<br>Not appealing color/fear color |
| Pineapple, Tunnel dryer | Nice aroma and smell<br>Sticky<br>Good balance between sweet and sour |
| Pineapple, Cabinet dryer | More moisture then the sample from the tunnel dryer, gives more taste<br>More sticky |
| Banana, Cabinet dryer | OK texture<br>Sweet |
| Banana, Tunnel dryer | Hard<br>Darker than the ones from the cabinet dryer<br>Sweet |