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Conservation Methods of Food of Plant Origin in the Tropics and Subtropics

Bachelor thesis

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Declaration

I, Eva Čelakovská, declare that I have elaborated my thesis independently and I have cited only literature listed in the References.

Prague, April 15th , 2016

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Eva Čelakovská

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Abstract

Fruits and vegetables are an indispensable source of human nutrition. Part of the thesis was focused on the classification of tropical and subtropical plants and their chemical composition. They took into account the traditional preservation methods of food of plant origin with regard to the applicability in tropical and subtropical areas and draw a comparison from various points of view. The part of the thesis was also paid to the factors influencing the development of microorganisms in biological and chemical aspects and to the originators of microbial changes.

Key words: food, preservation, microbiological processes, drying, salting, heating, sugar

Abstrakt

Ovoce a zelenina jsou nepostradatelným zdrojem výživy člověka. Část práce byla zaměřena na rozdělení tropických a subtropických plodin a jejich chemické složení. Dále byly zohledněny tradiční postupy konzervace potravin s ohledem na použitelnost v tropických a subtropických oblastech. Část bakalářské práce byla také věnována faktorům ovlivňujícím rozvoj mikroorganismů z biologického a chemického hlediska a původcům mikrobiálních změn.

Klíčová slova: potraviny, konzervace, mikrobiální procesy, sušení, nasolení, tepelná úprava, cukr

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1. Introduction

The concept of preservation is very broad. Each of preservation techniques changes environment, intervenes or modifiesthe stored product. These changes prolongs the shelf life for a longer period of time. Conservation also includes simple methods. However, they are not suitable for long time storage of food (Červenka and Samek, 2003).

Food preservation is the processing and handling of food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by bacterial, fungi and other microorganisms. Maintaining or creating nutritional value, texture and flavor are important in preserving its value as food. This is culturally dependent, as what qualifies as food fit for humans in one culture may not qualify in another culture (Gravani, 2011). Preservation usually involves preventing the growth of the microorganisms. It also includes a process to inhibit natural ageing and discoloration which can occur during food preparation (Sanii, 1993).

Feeding is necessary for any living being, providing a basis for good mental and physical development through its vital functions. Humans have been living by hunting and gathering fruits and vegetables that grew wild (Torres et al., 2016). With evolution, humans became sedentary and began to cultivate crops to meet their feeding needs. In the course of their development and evolution, humans tried to have access to food and to keep it without spoiling and with optimum quality. It led to the need to preserve it for later consumption (Ojha et al., 2016).

2. Objective

The objective of this thesis was the investigation of available literature sources and electronic information sources to analyze traditional conservation methods of food of plant origin to prevent or reduce the risk of proliferation of microorganisms to a minimum and to prolong the shelf life of plant products. Specific objective was to compare traditional preservation methods from different viewpoints and the best one chosen.points of view.

3. Methods

Collection of information on the topic was conducted from specific internet databases. The most used were: ScienceDirect (www.sciencedirect.com), Web of Knowledge (www.webofknowledge.com) and Google Scholar (www.scholar.google.com). To connect to ScienceDirect and Web of Knowledge the website of Czech University of Life Sciences (http://infozdroje.sic.czu.cz/) was used. Primary search terms used were „plant", „preserving" and „food spoilage". For the formulation of references the citations database EndNote (https://www.myendnoteweb.com) was used. All sources were listed in the list of references.

4. Literature Review

4.1. Characteristics of fruits

Fresh fruits mean edible fruits and seeds of trees and shrubs. Freshly picked fruit is put on the market immediately after harvesting or after a certain period of storage in a raw state. Processed fruit are products whose characteristic ingredient are fruit which were adjusted by preservation (Hrabě and Komár, 2003).

4.1.1. Classification of fruits

Citrus fruits

The main share of all forms of fruits consists of a pulp which is covered with a peel and hide seeds. The main fruits grow in subtropics and tropics include lemons (*Citrus limon*), oranges (*Citrus sinensis*), tangerines (*Citrus tangerine*), grapefruits (*Citrus paradise*), etc. (Hrabě et al., 2008).

Drupes

Outer skin covering a soft, fleshy fruit. The fruit surrounds hard stone or pit, for example coconuts (*Cocos nucifera*), pistachios (*Pistacia vera*), cashew nuts (*Anacardium occidentale*), mango (*Mangifera indica*), coffee (*Coffea arabica*), etc. (Nowak and Schulzová, 2006).

Pomes

A fruit consisting of a fleshy enlarged receptacle and a tough central core containing the seeds. Examples are apple (*Malus domestica*) and pear (*Pyrus spp.*) (Simpson, 2010).

Berries

Small, juicy fruits that contain many tiny seeds in the flesh. For example granadilla (*Passiflora ligularis*), passion fruit (*Passiflora edulis*), kiwifruit (*Actinidia chinensis*), etc. (Nowak and Schulzová, 2006).

Melons

Large, moist fruits that contain many seeds in the center or in the flesh. Melons have a thick skin that may be rough or smooth, e.g. cantaloupe (*Cucumis melo* var. *Cantalupensis*) and casaba (*Cucumis melo* var. *inodorus*), watermelon (*Citrullus lanatus*), etc. (Hrabě et al., 2008).

Tropical fruits

They grow in warm sunny places. Many of them fit into the different categories already discussed. E.g. pineapple (*Ananas comosus*), banana (*Musa sapienta*), carambola (*Averrhoa carambola*), papayas (*Carica papya*), dragonfruit (*Hylocereus undatus*), etc. (Simpson, 2010; Welbaum, 2015).

4.1.2. The importance of fruits in human nutrition

Fruits have an irreplaceable role in human nutrition, especially fresh fruits. Fruits give essential vitamins to the body (vitamin A, a group of vitamins B, vitamins C, E and others), as well as enzymes, minerals (iron, potassium, calcium, sodium, and others). An important component in fruits is fiber, mineral salts and pectin (Lehori and Colditz, 2002). They support the digestive activity of human organism, and divert harmful substances from the organism. Fruits are increasingly important in human nutrition. The optimal consumption of fruits per one person should be between 80-100 kg per year (Valíček et al., 1995). During the international research program for crops in the Southeast Asia there were found 700 plant species, their fruits are used as a food source (Jones et al., 2001).

4.1.2.1. **The importance of tropical and subtropical fruits**

About 90 % of growing species in the tropics and subtropics are given to be consumed (Nowak and Schulzová, 2006). The tropical and subtropical fruits are a source of building materials, fuel, medicines, fibers, oils, resins, and last but not least, the food source. A variety of fruits such as peppers, bananas, oranges, coffee and cocoa are in daily use by consumers in colder regions of the world for centuries. Maintaining the diversity of fruits and their understanding is very important for ensuring the food sources and diversity in the diet of the population of tropical countries (Rohwer, 2002). Relocating to the cities, the destruction of traditional culture and the extinction of plant species by deforestation threaten this wealth as well as the industrialization of an economy and turning away from the subsistence livelihoods (Valíček et al., 2002).

4.1.3. Chemical properties of fruit

Fruits are an important source of vitamins, minerals and various specific active substances that promote proper development of the organism and contribute to the preservation and reinforcement of its good health (Šrot, 2005).

4.1.3.1. **Water**

Fresh fruit contains 79 – 87 % of water. To the contrary, nuts in consumer ripeness contain 5 – 16 % of water (Šrot, 2005).

4.1.3.2. **Saccharides**

Fruits contain saccharides in concentration of 5 – 15 %. Fruits contain mainly glucose, fructose and sucrose in particular fluctuating ratio. The amount of sugar in the fruits varies not only by species and variety but also depending on climatic and soil conditions, including fertilizers and crop size. Starch, cellulose, hemicellulose, pentosans, and pectic substances are the main polysaccharide components. Starch is a component of unripe fruits and during ripening it is removed. Cellulose, hemicellulose and pentosans are component of fruit pulp, seeds, cores and peelings (Hrabě and Komár, 2003). Fructose (fruit sugar) prevails in the fruits with cores. Glucose (grape sugar) prevails in pip fruit. In soft fruits the content of glucose and fructose is approximately identical and sucrose content is minimal (Giangiacomo et al., 1987).

4.1.3.3. **Proteins**

Proteins have an irreplaceable energetic importance in the nutrition of organism. In fresh fruits the content of protein is usually in the range of 0.40 to 1.50 %. The highest content of nitrogen contains berry fruit, less pip fruit and at least the core fruit. The weather during the growing season has an influence on the protein content in fruit. Usually in dry years fruits contain more nitrogen than in wet years. During a substantial loss of protein, content of sugars grows relatively fast (up to 4%) (Jílek, 2001).

4.1.3.4. **Vitamins**

Fruit has higher level of vitamin C than the other vitamins. It is very important because vitamin C increases the body´s resistance against diseases and fatigues.

Its content fluctuates according to species and varieties, depending on the degree of maturity, harvest time, length and conditions of storage. The daily consumption of vitamin C is about 60 – 70 mg per an adult person (Šrot, 2005). Vitamin A is contained in the fruit as provitamin carotene. Carotenoids contribute to the coloration in most fruit species. Important is the content of beta carotene in orange. The total carotenoid content in oranges is 3 $mg.100^{-1}$ ml of juice. Vitamin A promotes normal development of the mucous membrane and the retina. Vitamin A also increases resistance to infections. Vitamin A is an unstable dark-red crystalline solid. Provitamins are substances which are converted in the body by biochemical processes to the respective vitamins (Jílek, 2001). B complex vitamins support especially the good function of the nervous system and various metabolic processes in the body (Šrot, 2005).

4.2. Characteristic of vegetables

The term vegetable is used to describe the tender, edible shoot, leaves, fruits and root of plants and spices that are consumed whole or in part, raw or cooked. Vegetable is any part of a plant that is consumed by humans as a food. Vegetable is somewhat arbitrary and largely defined through cultural tradition. It normally excludes other food derived from plants such as fruits, nuts and cereal grains, but includes seeds such as pulses (Gopalakrishnan, 2007).

4.2.1. Classification of vegetables

Leafy vegetables

The leaves and succulent young shoots are picked for consumption. Examples are amaranth (*Amaranthus spp.*), celosia (*Celosia spp*.), pumpkin (*Cucurbita pepo*), lettuce (*Lactuca sativa*), cabbage (*Brassica spp.*), bitter leaf (*Vernonia Amygdalina*), jew mallow (*Corchorus olitorius)* and fluted pumpkin (*Telfairia occidentalis*) (Niir, 2004).

Fruit vegetables

This comprises of young, immature unripe fruits or mature ripe fruits of plants grown as vegetables. Examples are cucumber (*Cucumis sativus*), tomato (*Solanum lycopersicum*), okra (*Abelmoschus esculentus*), eggplant (*Solanum melongena*), watermelon (*Citrullus lanatus*) and sweet pepper (*Capsicum annuum*) (Ghai and Arora, 2007).

Root vegetables

The definition of root vegetables is an edible plant where the roots are used as vegetables - basically, root vegetables are vegetables grown underground. This group consists of vegetables such as sweet potato (*Ipomoea batatas*), Irish potato (*Solanum tuberosum*), carrot (*Daucus carota*) and radish (*Raphanus sativus*) (Ghai and Arora, 2007).

Spices

Spices are important for their flavor and color in foods such as chili pepper (*Capsicum annuum*), garlic (*Allium sativum*) and basil (*Ocimum basilicum*) (Welbaum, 2015).

4.2.2. The importance of vegetables in human nutrition

Vegetables supply most of the nutrients that are deficient in other food materials. This includes supply of minerals, especially calcium and iron. Vegetables are acid neutralizers e.g. okra (*Abelmoschus esculentus*), white juta (*Corchorus capsulari*) neutralizes the acid produced from the some fruits. Vegetables prevent constipation and promote digestion as a result of fibres/roughages obtained from okra, cucumber (*Cucumis sativus*), amaranth (*Amaranthus spp.)*, lettuce (*Lactuca sativa*) and cabbage (*Brassica spp.*). Vegetables are great sources of vitamins A, B, and C which helps to lower susceptibility to infection. e.g.: Carrots (*Daucus carota*), sweet corn (*Zea mays*), amaranthus and celosia (*Celosia spp.*) provide Vitamin A. Bitter leaf (*Vernonia amygdalina*), water leaf (*Hydrophyllum virginianum*), eggplant (*Solanum melongena*) provide Vitamin B; Tomatoes (*Solanum lycopersicum*), carrots, lettuce, cabbage and amaranthus provide Vitamin C. Also, some vegetables are great sources of carbohydrate e.g. potatoes (*Solanum tuberosum*), sweet corn, carrot etc. Green beans (*Phaseolus vulgaris*) and peas (*Pisum sativum*) are cheap sources of protein. Vernonia (bitter leaf), amaranthus and oyster nut (*Telfairia pedata*) provide some amount of protein in human diet. Vegetables are generally needed to balance diets and overcome nutritional deficiencies. Vegetables make our staple food more palatable and enhance their intake (Gopalakrishnan, 2007; Sandeep et al., 2016).

4.2.3 Chemical properties of vegetable

Vegetables contain essential nutrients such as carbohydrates, proteins, fats and also a number of the specific substances necessary for human health. Among the essential nutrients are particularly vitamins, minerals, cube fiber, essential oils and other protective medical substances (Šrot, 2005).

4.2.3.1. **Water**

Water is a basic component of vegetable. Especially for vegetables, the content of water constitutes 75 – 95 %. The content of the water depends on many factors. The most important factors are climate, growing conditions, age of plant, level of maturity, etc. (Jílek, 2001).

4.2.3.2. **Saccharides**

Vegetables contain around 7 % of carbohydrates. They are in the form of sugars, starch, inulin, crude fiber and organic acids. Glucose and fructose are in almost all vegetables. Sucrose and various polysaccharides are occurring beside these. Structural component of a cell wall is the group of the polysaccharides includes vegetable starch and pectins. The starch at a mature stage is hydrolyzed to glucose (Hrabě et al., 2008).

4.2.3.3. **Mineral substances**

Mineral substances are also called ash substances because when the food is totally burned the individual elements remain as ash. The content of minerals in vegetable is 1.0 - 2.0 %. During the processing it is necessary to have permanently in memory content of the minerals in the vegetable because by using unappropriate technology, are the losses of mineral substances higher than 50 % (Jílek, 2001).

4.2.3.4. **Proteins**

Proteins are formed from nitrogenous substances. Approximately 20 – 65 % of nitrogenous substances are attributable to non-protein components (amino acids, amines). Vegetables with intense green leaves (e.g. spinach) have a lot of protein and essential amino acids and also legumes have great content of the protein (22 – 24 %) (Hrabě et al., 2008).

4.2.3.5. **Enzymes**

Enzymes play a significant role in the storage and processing that can change a variety of substrates. Enzymes contained in the vegetables and fruits generally produce deterioration, particularly they change the color, change the consistency, occurs the degradation of substances to substances with bad smell, and sometimes are also toxic.
Non-enzymatic browning plays a role mainly during the drying. Browning changes are especially with the presence of oxygen. During the storage changes are influenced by the temperature. Non-enzymatic browning depends on the reducing sugars, organic acids, amino acids, amines, and other materials (Hrabě et al., 2008).

4.2.3.6. **Vitamins**

Vitamin C is one of the most important components of vegetables. The content of vitamin C is higher in leafy vegetables than in edible fruits of vegetables. The content varies according to the species and varieties, depending on the degree of maturity, harvest time, length and conditions of storage. The content of folacin is directly related to the content of chlorophyll. Pantothenic acid occurs in various parts of the plants (Jílek, 2001).

4.2.3.7. **Chlorophyll**

A green coloring of the leaves and unripe fruit is caused by blue-green chlorophyll A and yellow-green chlorophyll B, which occur in the ratio 3: 1. In the chloroplast is chlorophyll bounded to the proteins and to the lipoproteins. This gives the stability against light and oxygen (Jílek, 2001).

4.3. Food spoilage

Food spoilages are undesirable changes taking place in the food. It means the original nutritional value, texture, and flavor of the food are damaged. The food becomes harmful to people and unsuitable to eat. Food spoilage can be caused by the following factors (Shahidi et al., 2013):

1) Mechanical effect
2) Action of enzymes present in the food

3) Physicochemical reaction in the food
4) Action of microorganisms, e.g. bacteria, yeast and molds

4.3.1. Mechanical effect

It is the kind of damage, when the natural shape and structure of the raw material are disturbed. For example mechanical effects are damaged by animals, pests, during the harvesting, during the processing or distribution. This damage increases the chance of chemical or microbial spoilage and contamination. It is because the protective outer layer of the food is bruised or broken and microorganisms can enter the foodstuff more easily (Eskin and Shahidi, 2012).

4.3.2. Action of enzymes present in the food

Enzymes are also called specialized proteins. Every living organism uses proteins to drive chemical reactions in its cells. In a process called autolysis (self-destruction) or enzymatic spoilage enzymes play a role in the decomposition of once-living tissue. For example, some enzymes in tomatoes help to ripen, by contrast to other enzymes which cause decay (Sandeep et al., 2016).

When the cells of fruits and vegetables are trimmed (e.g. apples, potatoes, bananas and avocado) and exposed on the air, enzymes present in the cells converted colorless compounds into brown-colored compounds by the chemical reaction. This is called enzymatic browning. If the food are cooked very soon after cutting, the enzymes are destroyed by heat and the browning does not to occur. For example, apples are prone to discoloration when they are cut in a raw state, but after cooking they become resistant to browning. (Mesquita and Queiroz, 2013; Shahidi et al., 2013).

4.3.3. Physicochemical reaction in the food

4.3.3.1. **Moisture content**

Water is one of the basic conditions for the biochemical reactions. Raw materials containing water or raw materials stored in humid conditions succumb to biochemical changes more easily than raw materials stored in a dry place. The large storage humidity leads to an increase of humidity and to an accelerated undesirable processes (e.g. change colors, taste, smell and consistency) (Pomeranz and Meloan, 2002). The water content in safe products vary from product to product and from formulation to formulation. One safe, stable product might have a water content of 15 % while another with a water content of 8 % is susceptible to microbial growth. This is so because the microbial stability or physicochemical properties of food are often determined by amount of free water (Shahidi et al., 2013). Microorganisms need a moist environment to grow in. In the Tab. 1 are shown some examples of the microorganisms and their water requirements. The microorganisms have water requirements which are described in terms of water activity (represented by the symbol a_w), a measure of how much water is present. The water activity of pure water is a_w = 1.00. Most foodborne pathogenic bacteria require a_w to be greater than 0.9 for growth and multiplication; however, *Staphylococcus aureus* may grow with a_w as low as 0.86. But even *Staphylococcus aureus* cannot grow and multiply in dried foods, which has a_w = 0.7, although fungi can, according to FAO (2008).

Tab. 1: Common spoilage organism and their a_w limits for growth (AQUA LAB, 2016)

Microbial group	**Example**	**a_w**	**Products affected**
Normal bacteria	*Clostridium botulinum*	0.91	Fresh fruit
Normal yeast	*Torulopsis species*	0.88	Fruit
Normal molds	*Aspergillus flavus*	0.80	Fruit and vegetables
Halophilic bacteria	*Wallemia sebi*	0.75	Dried vegetables and fruits
Xerophilic molds	*Aspergillus echinulate*	0.65	Vegetables
Osmophilic yeast	*Saccharomyces bisporus*	0.60	Dried fruit

4.3.3.2. **Potential of hydrogen – pH**

The scientific term pH is a measure of how acidic or alkaline an environment is, on a scale that has neutral (neither acid nor alkaline) at pH 7. Tab. 2 shows various species of the fruits and vegetables and their potential of hydrogen. Environments that are acidic have pH values below 7; those that are alkaline have pH values above 7. Most microorganisms grow best at close to the neutral pH value (pH 6.6 to 7.5). Only a few microorganisms grow in very acid conditions below a pH of 4.0. Bacteria grow at a fairly specific pH for each species, but fungi grow over a wider range of pH values (Blackburn, 2006).

Tab. 2: pH values of various species of fruits and vegetables
(U.S. Food and Drug Administration, 2015)

Vegetables	pH	Fruits	pH
Cauliflower	5.6	Cantaloupe	6.17 – 7.13
Cabbage	5.2 – 6.0	Melon	5.5 – 6.3
Cucumber	5.1 – 5.7	Papaya	5.2 – 5-7
Pepper	5.15	Banana	4.5 – 5.2
Pumpkin	4.8 – 5.2	Mango	3.9 – 4.6
Eggplant	4.5 – 5.3	Pineapple	3.3 – 5.2
Sauerkraut	3.4 – 3.6	Orange	3.1 – 4.1
Tomatoes	4.2 – 4.9	Lemon	2.2 – 2.4

4.3.3.3. **Temperature**

Temperature of the environment has a significant influence on the course of chemical and microbiological processes. The temperature can accelerate, decelerate or stop the processes. At normal temperature about 20°C various changes arise stimulated by microbial activity, color changes caused by the activation of enzymes and oxidative changes. These transformations can be braked by low temperatures (Pomeranz and Meloan, 2002). Uncut, fresh fruits and vegetables such as bananas, lemons, squash and tomatoes are products that should be held at temperatures not colder than 10°C for the best quality (Blackburn, 2006). Different microorganisms grow over a wide range of temperatures as shown in Tab. 3. Some microorganisms require conditions for growth in cold temperature, some require conditions for growth at room temperature and others grow at high temperatures. This is of paramount importance in food safety, because the thermal growth is for dangerous undesirable microorganisms, it is necessary to select the proper temperature for food storage to make them less able to grow and reproduce (Barth, 2009).

Tab. 3: Classification of bacteria according to temperature requirements

(Moutney et al., 1988)

Temperature required for growth °C				
Type of bacteria	Minimum	Optimum	Maximum	General sources
Psychrophilic	0 to 5	15 to 20	30	Water and frozen foods
Mesophilic	10 to 25	30 to 40	35 to 50	Pathogenic and non-pathogenic bacteria
Thermophilic	25 to 45	50 to 55	70 to 90	Spore forming bacteria from soil and water

4.3.3.4. **Oxygen**

One important cause of food spoilage is air and oxygen. Because air is colorless, odorless, and tasteless, it is often taken for granted and sometimes forgotten as a cause of food spoilage. Air consists of 78 % nitrogen, 21 % oxygen, and a 1 % mixture of other gases. While oxygen is essential for life, it has undesirable effects on fats, food colors, vitamins, flavour, and other food constituents (Gravani, 2001). Many microorganisms need oxygen for development and reproduction: these are called aerobic microorganisms. A good example is *Escherichia coli*, a faecal bacteria which grows readily on many foods (Pitt and Hocking, 2009). Conversely, there are some microorganisms that grow without oxygen, called anaerobic microorganisms. An example of this is *Clostridium botulinum*, the bacterium causing botulism, which can survive in very low oxygen environments such as tinned foods (Sandeep et al., 2016). Basically, oxygen can cause food spoilage in several ways. It can provide conditions that will enhance the growth of microorganisms or it can cause damage of foods with the help of enzymes and it can cause oxidation (Pitt and Hocking, 2009).

4.3.4. Action of microogranisms

Microorganisms are the main and the most frequent cause of food spoilage. Outwardly, spoilage manifests differently, e.g. changing the clarity of the liquid, consistency of materials, colors, flavors and fragrances, etc. (FAO, 2005). Microorganisms have a different form. They are a very small organisms, usually unnoticeable by the eye. The microorganisms include bacteria, yeasts and fungi.

Microorganisms are all around us, they reproduce on the surface of the body, they are found in the digestive tract of humans, in the air, in the water, they are also present in the raw materials and on dishes (Šilhánková, 2002). The presence of some observable microorganisms with the naked eye can be recognized only when they are strongly propagated (from one cell to several million). Then they can create so-called "colonies". If the food is contaminated by harmful and any unwanted microorganisms, it means "contamination" (FAO, 2005).

4.3.4.1. **Bacteria**

Bacteria are spiral, round or rod microorganisms. Bacteria can grow under a wide diversity of conditions. They universally prefer low acid foods like vegetables. Well-known are family *Lactobacillaceae* and *Acetobacter* species which are present in the fermentation of fruits and vegetables. Eating spoiled food caused by bacteria can cause food poisoning (Kraft, 1992).

4.3.4.2. **Molds**

Molds are also important in the food industry. Some molds produce unwanted toxins. The *Aspergillus* species are frequently found in foods which tolerate high concentrations of sugar and salt. Molds are aerobic and need oxygen for growth. Molds can thrive in high acid foods like fruit, jams and tomatoes. They can be easily destroyed by heat (Barth et al., 2009). The main symptoms from eating moldy food may be vomiting or nausea from the smell and from the bad taste of the moldy food (Kraft, 1992).

4.3.4.3. **Yeasts**

Yeasts and yeast-like fungi are widely distributed in nature. There are about two types of yeasts. The first one is true yeast which metabolizes carbon dioxide gas and sugar producing alcohol. The best-known fermenting yeast is *Saccharomyces* family, especially *S. cerevisiae.* The name of this processes is fermentation. The second type is false yeast which grows as a film on the surface of foods (Fig. 1). False yeast can be found in foods that have a high acid environment or high sugar (Blackburn, 2006).

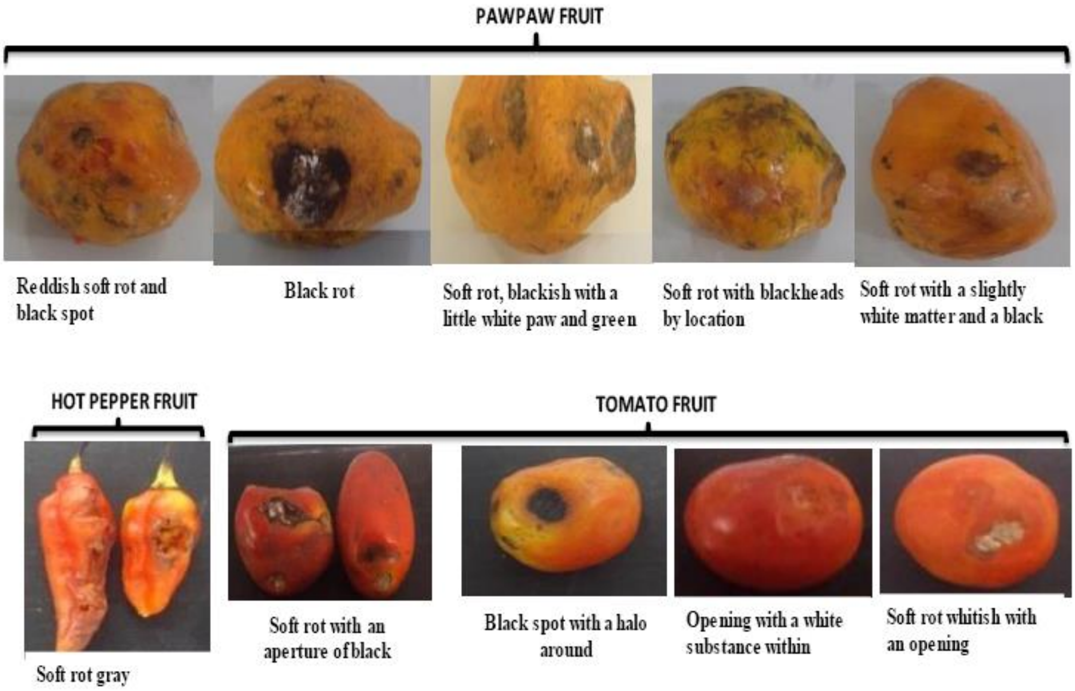


Fig. 1: Description of fungi disease symptoms on fruits (Kossonou et al., 2014)

4.4. Food preservation

Food preservation ensures a reduction of microorganisms to a minimum, and regulates changes in the food. Preservation prolongs the shelf life of products and the degradation processes of food until in the human body. (Jílek, 2001). The basic task is to improve or preserve the taste, aroma and content of certain ingredients (e.g. vitamins) (Červenka and Samek, 2003).

4.4.1. Preparation

Within 48 hours after harvesting fruits and vegetables should be prepared for preservation as soon as possible. The probability of the food spoilage increases depending on time (James and Kuipers, 2003).

4.4.1.1. **Cleaning and washing**

It is a compulsory processing step which must be done before cutting to maintain the nutritive value (vitamins, minerals, etc.). Vegetables and fruits have to be carefully cleaned to eliminate insecticides, microorganisms and any dirt (e.g. sand or soil). For cleaning, spray, bucket or clear running water can be used. Water should be free from yeast and molds. Because of yeast and mold a solution of hydrochloric acid (1.5 %) should be added to the water (Axtell et al., 2008).

4.4.1.2. **Sorting**

Sorting is a process used after cleaning to separates the raw materials into categories according to the weight, size, shape etc. Especially sorting by size is important if the products will be dried or heated; it can determinates how much time will be needed for these processes (James and Kuipers, 2003). The shape sorting can be achieves mechanically, for example with a belt-roller, or manually. Weight sorting is very exact method used for the superior foods (tropical fruits, certain vegetables, etc. (Leistner, 1992).

4.4.1.3. **Peeling**

Peeling improves the taste and appearance of the final product. During the peeling care is needed to minimize losses. Peeling can be done with a stainless knife. Extremely important is quality of the material. Knives made from stainless steel prevent the discoloration of the plant tissues (James and Kuipers, 2003).

4.4.1.4. **Cutting**

This step is executed according to the uniform pieces for the drying, heating, etc. Vegetables and fruits are commonly cut into rings, thin slices, cubes or shreds. When the fruits and vegetables are cut, the quality of the products decreases. The interval between cleaning – sorting – peeling - cutting and the last step preserving should be as short as possible, according to FAO (2005).

4.4.1.5. **Blanching**

Fresh vegetable, fruits and pieces of root vegetable are submerged in a bath containing 91-99°C hot or boiling water for 1-10 minutes. The boiling time will depend on the type of fruit or vegetable. After boiling crops became soften (Abhakorn, 2000).

This method is fairly simple. For blanching a large pan is used with a lid and metal colander. Instructions for blanching are shown in Fig. 2. The principle of this method is put the vegetable or fruit in the colander and submerge it in a pan with nearly boiling water covering the food completely, let the pan submerge for several minutes then remove and rinse with cold running water. Drawbacks of blanching are that in the hot water many vitamins are lost (Bearman and Kissel, 2000).

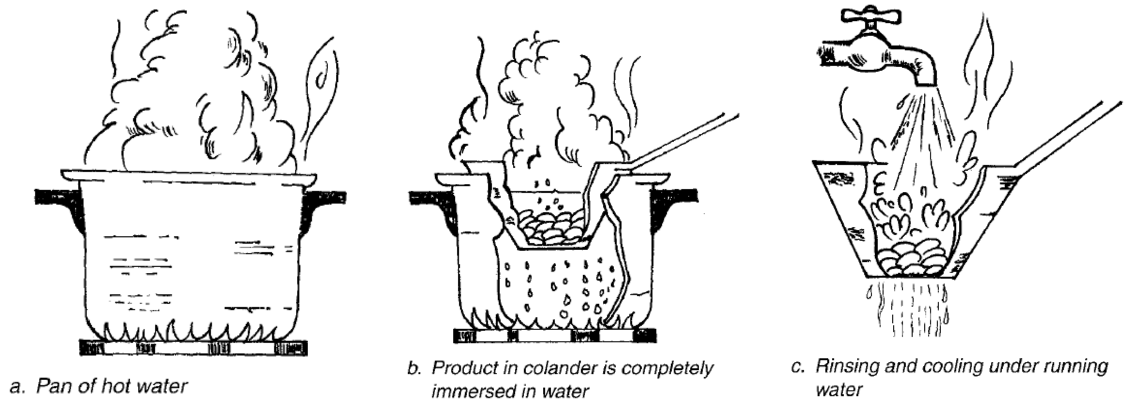


Fig. 2: Blanching (James and Kuipers, 2003)

4.5.2. Preservation methods

4.5.2.1. **Preservation by heating**

One of the most common method to preserve vegetables and fruits is preservation by heating. At first crops must be prepared and then can be placed in containers (e.g. iron cans or glass jars), which must be airtight. These containers are then heated in hot water. The high temperature guarantee the activation of enzymes and kill the microorganisms. The heating method is for the most vegetables different than for the fruit. Fruits can be heated in boiling water because of low pH level, while most vegetable have a higher pH and have to be heated at temperatures above 100°C (Leistner, 1992).

The most common kinds of the tropical and subtropical fruits preservation by heating are mangoes, pomelos, guavas, oranges, pineapples, etc. from which can be made marmalade, syrups and jams. Kinds of vegetables preservation by heating are tomatoes, onions, cabbages, yams, sweet potatoes, etc.

4.5.2.1.1. **Pasteurization**

Pasteurization is a mild heat treatment to the boiling point of water (temperatures up to 100°C). This method only slightly reduces the taste and nutritional value. The products preserved by pasteurization will spoil faster than products of sterilization. Therefore they should be stored in temperatures below 20°C (Bearman and Kissel, 2000).

Figure 3 shows how pasteurization is carried out. The products are pasteurized in a closed glass or tin containers in boiling water. It is important that the lid of a glass jar fit well because of air which can escape during the heating. After removing the jar from the pan it is necessary to cool them. Within the container arisen a vacuum and food has no chance come to contact with the air. Time of pasteurization depend on the kind of plant product. It can be from 10 to ± 20 minutes (James and Kuipers, 2003).

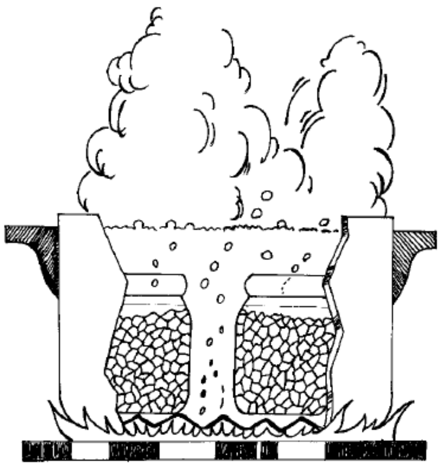


Fig. 3: Jars in a pan (James and Kuipers, 2003)

4.5.2.1.2. **Sterilization in a bath of boiling water**

Sterilization means complete destruction of microorganisms but not the spores they produced. The water is boiled at 100°C and it is not enought for destruction of spores. Spores grow an acid environment. Because of it is added sugar or acid to the preservation. This ensures that even when heated only to 100°C, the product will be sterilized and its shelf life is extended (Leistner, 1992).

4.5.2.1.3. **Sterilization with a pressure cooker or autoclave**

Sterilization in an autoclave, as shown in Fig. 4, kill all microorganisms and also the spores they produced and therefore the shelf life is lengthened without adding extra sugar or acid. In pressure cooking the boiling point of water is a temperature higher than

100°C (from 115°C to 121°C), depending on a pressure. For the most vegetables and all foods with a high pH is sterilization at a temperature above 100°C the best. Temperature and preservation time depend on the type of crops (Dauthy, 1995).

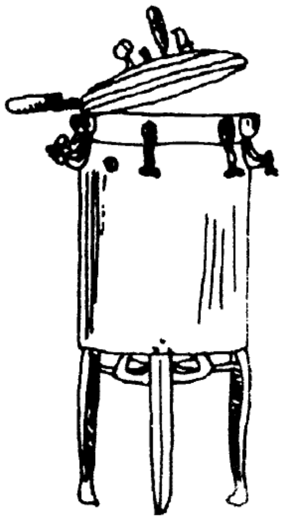


Fig. 4: Autoclave (James and Kuipers, 2003)

4.5.2.2. **Drying**

Preservation by drying is one of the oldest preservation method. The moisture level of plant product is reduced to 10-15 % so that the present microorganisms cannot prosper and the enzymes become inactive. Products become brittle after dehydration and therefore this method is not always suitable (Dauthy, 1995). The final products must be stored in a moisture-free environment to prevent spoilage. Drying is not difficult method. Due to the fact that the products loses water are much lighter and therefore easier to transport (Lucia and Assennato, 1994). Drying has some disadvantages e.g. the products loses proportional part of vitamins, changes the appearance and color.

The most common method of drying is put products in the air. Air absorbs water; the more will be air warm, the more will be water absorb. For best results, the air should be dry, hot and in motion (Abhakorn, 2000). Bearman and Kissel (2000) have also reported that the ideal relative humidity for drying is less than 65 %. Fruits and vegetables can be dried even at a relative humidity higher than 65 %, but the resulting products can easily succumb to spoilage. The best drying is in combination with sunshine, where the relative humidity is much less than 60 %. Rain and clouds are not ideal for drying because the humidity is much higher than 70 %.

Fruits and vegetables must be prepared before drying and then spread on drying trays. Some examples are shown in Tab. 4. Most species of tropical and subtropical fruits can be preserved by drying. The most common kinds are bananas, mangoes, kiwifruit, peaches, pineapples, papayas, coconuts, ginger, etc. The most common products made from vegetables by drying are dried cabbages, dried okras, dried onions and dried yams.

Tab. 4: Fruits and vegetables - preparation and drying conditions
(James and Ngarmsak, 2010)

Product	**Preparation**	**Spread on tracks, remarks**
Bananas	Peel and cut in half length-wise or slice	One layer thick with the cut side up
Peaches and Mangos	Wash, halve, remove pits	Spread with the cut side up
Pineapples	Peel and cut into thin slices	One layer
Grapes	No usual preparation, sometimes a lye dip is given	One layer thick with the cut side up
Chili	Wash	More layers, regular rotation
Onions	Peel, cut into thin slices	More layers, regular rotation
Yams	Wash, cut into slices	One layer
Eggplant	Wash and halve	Spread with the cut side up

4.5.2.2.1. **Natural drying**

Natural drying is drying in the open air, exposed to sunlight. Some products do not like direct sunlight, so a shady spot is better for them. This is a relatively cheap and easy way. The advantages of this method is just the need of sun and wind. No further costly energy (Barbosa-Cánovas et al., 2003). The products are dried on thin trays, usually made from wood and lined with galvanized or plastic nets (Fig. 5). James and Kuipers (2003) have also written that the trays should be placed on the racks on a straight surface at least one meter above the ground to prevent contact with dirt and other contaminants. Alternatively, trays can be covered for protection against rain, birds and other pests. Mosquito net is the best and most effective method of control. It is necessary that the vegetables or fruits are dried evenly. As needed, for a good drying significant regular rotation or shaking with the trays is needed. This applies only to fruits and vegetables which are arranged on trays in layers.

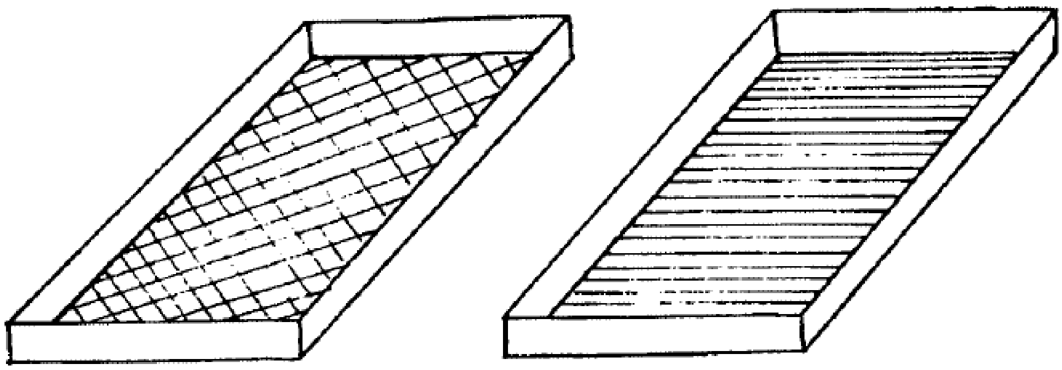


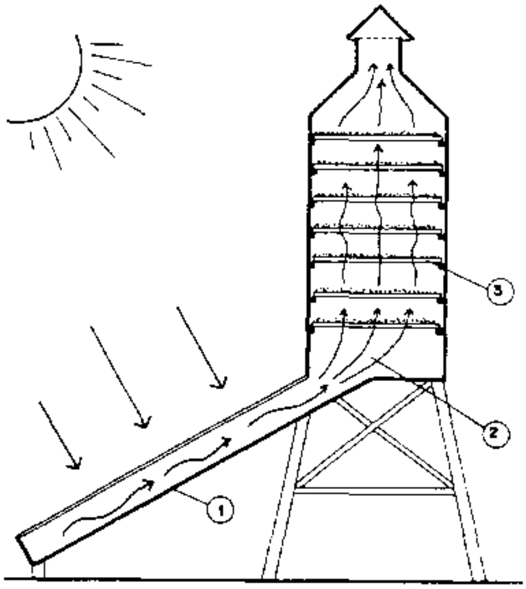
Fig. 5: Drying trays (James and Kuipers, 2003)

4.5.2.2.2. **Artificial drying**

Sometimes the air temperature is too low to make air drying possible. Therefore it is necessary to artificially increase the temperature by a few degrees. For example, according to FAO (2005), due to the relative humidity during rain the required drying temperature for fruits and vegetables will increase from 30°C to 37°C. Air can be heated through solar energy or by burning fossil or natural fuels (Lucia and Assennato, 1994). Leistner (1992) has also reported that the maximum drying temperature is important for the final product, whose quality decreases inversely with the rate of drying. An advantage of artificial drying is that the product dried rapidly on the outside while inside is still moist (Lucia and Assennato, 1994).

Solar drying

So called improved drying is drying on the trays that are placed in the structure (Dauthy, 1995). This method is very fast and allows drying even in damp areas. As you can see in Fig. 6, this is an indirect drying, because sunlight does not come into contact with the products. Sun rays penetrate across the glass cover (Lucia and Assennato, 1994). Because the solar heat is caught in the structure, the temperature rises to 60-75°C. The temperature inside the structure can reach to 90-100°C and thus leads to overheating. The problem with overheating is resolved by ventilation that removes excess heat, and prevent condensation on the glass. Dauthy (1995) have also reported, that this technique is very suitable for drying even in humid areas, since the relative humidity decreases with higher temperature and also products are generally protected against the rain.



1. Solar panel; 2. Hot,dry air; 3. Products to be dried

Fig. 6: Diagram of solar dryer (Lucia and Assennato, 1994)

The bush dryer

This method is based on the principle of the dryer. For drying a fuel is used. A fire in an oven made from oil drums heats the surrounding air. Products are placed on racks in thin layers through which warm air rises (see Fig. 7). Products should be periodically stirred or shaken (James and Kuipers, 2003). Throughout the drying, fire must be monitored to avoid burning of the products. Part of the dryer can be ventilator, which blows warm air ahead of the products. Dauthy (1995) has also reported that the advantage of this method is faster drying of vegetables than on the sun, and the specific taste, colour and aroma of the final products. A big disadvantage are the construction costs, high fuel costs and precise work during the construction of the dryer.

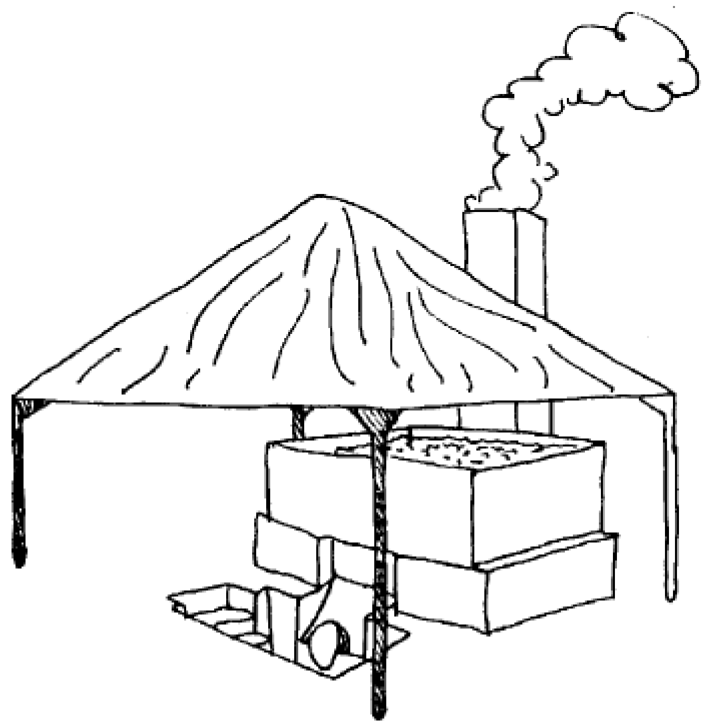


Fig. 7: Bush dryer (James and Kuipers, 2003)

4.5.2.3**. Preserving with sugar**

Sugar is used for fruit preservation because sugar increases the osmotic pressure of the liquid phase of the product. Osmotic drying means immersing the fruit in a sugar solution with a concentration of 40-60 %. Fruit made by this method is called candied fruit (The Gardeners and Farmers of Centre Terre Vivante, 2007). It refers a process of preparation and initiation drying fruit, because sugar extracts water which is contained in the fruit. Fruit during soaking in solution absorbs a certain part of the sugar and the fruit is able to retain more water during the drying process. It makes the products softer than if they were only air dried without the use of sugar solution (Lucia and Assennato, 1994). During preservation with sugar should not decreases the water activity below 0.845; this value is sufficient to prevent the development of microorganisms, but not to the development of fungi (see chapter 3.3.3.1. Moisture content). The best way is to precook the fruits, thereby removing water from the product and subsequently increases the concentration of sugar. Depending on the type of product used with direct or indirect sunlight. According to FAO (2005), the best results are obtained when the solution of sugar is 40% and the product is immersed for 18 hours. What is important is proportion of sugar in the final product and the total sugar concentration in the liquid phase because it determines the preserving action of sugar (Barbosa-Cánovas et al., 2003). Long-term storage of the final products can be achieved only in suitable conditions with a minimum amount of moisture. Conservation with sugar improves the texture, flavor, color, etc. and counteracts against mushiness of the final product. The great advantage of osmotic drying is the prevention of browning and the prevention of discoloration (James and Kuipers, 2003).

All kinds of the tropical and subtropical fruits can be preserved by sugar. For example pomelos, mangoes, guava, oranges, papayas, pineapples, carambolas, etc. Cruess (2008).

4.5.2.4. **Preserving with salt**

Conservation by adding salt is one of the oldest methods of vegetables preservation, especially in areas where there is easy access to cheap salt. Salt due to its characteristics absorbs water from vegetables and for microorganisms it is very difficult to survive in this environment (Battcock and Azam-Ali, 1998). Vegetables must always be prepared before preservation and the best method must be chosen. Some of the best methods are shown in Tab. 5.

There are two types of salting used depending on number of salt. Using a large amount of salt is also called heavy salting. It is relatively less demanding and an easier method than conservation with a small amount of salt, also called light salting. Approximately 5 parts of vegetables is used for 1 part salt. This makes the vegetables very salty and because of it must be rinsed several times in water (Bearman and Kissel, 2000; Leistner, 1992). The disadvantage of using a large quantity of salt is the negative effect on the taste of the final product. This can be prevented by soaking or rinsing vegetables in the water before it is consumed. Therefore, use of 20- 25% concentration of salt is suitable only if the quantity of fresh vegetables is sufficient and there is no other way of conservation. Adding a small amount of salt to the vegetables creates appropriate conditions for the growth of microorganisms. On the other hand, a small amount of salt multiplies a certain type of bacteria. This certain type of bacteria produces an acid which reduces the growth of other bacteria. The salt can be used like a salt-water solution in the form of sodium chloride (heavy or light brine) or as a dried granules. The color, odor and taste are better when preserved with salt than with brine (Cruess, 2008; Welbaum, 2015).

Tab. 5: Preparation of vegetables for salting and the best method for each type of vegetable (U.S. Food and Drug Administration, 2015)

Product	Preparation	Method
Cabbage	Remove outer leaves and stalks; shred	Light salting
Cauliflower	Remove stalks and leaves; cut into small pieces; no cutting is needed with the heavy brine method	Light salting Heavy salting
Kale	Trim leaves; wash well, use the whole leaves	Light brine
Lettuce	Wash, remove outer leaves and stalk, shred	Light salting
Okra	Cut ripe okra into small pieces	Heavy salting Heavy brine
Sweet pepper	Cut length-wise, remove seeds and stem	Heavy brine
Green tomatoes	Wash well, do not slice	Light brine

4.5.2.5. **Fermentation**

Fermentation, also called lacto-fermentation is traditional and a very healthy way of processing vegetables (The Gardeners and Farmers of Centre Terre Vivante, 2007). Fermentation is an ancient method of food preservation and is one of the most important elements of healthy and natural food, mainly for their irreplaceable content of probiotic bacteria. Lacto-fermentation is a process of conversion of carbohydrates contained in vegetables into lactic acids due to the ubiquitous fermenting bacteria *Lactobacillus acidophilus*. The process of fermentation uses a brine which creates an anaerobic, acid environment (Battcock and Azam-Ali, 1998).

By this method large amounts of vitamin C, enzymes, minerals, lactobacilli and lactic acid arises. The products preserved by fermentation gives a light, refreshing taste and helps to maintain or build healthy intestinal flora in the body, which is essential for proper digestion and enhances the nutritive value of the food (Leistner, 1992; Bearman and Kissel, 2000).

Many kinds of vegetables can be made by fermentation. For example carrots, onions, radishes, radish, beetroot, cabbage, cucumbers, zucchini, cauliflower, cabbage, etc. The most common product is sauerkraut. While a cabbage might rot within a couple of weeks at room temperature, sauerkraut can be kept for months, and in some cases years (Welbaum, 2015).

4.5.2.6. **Preserving with vinegar**

Preserving with vinegar is also called pickling. Vinegar is produced from starches or sugars, first fermented to alcohol and then the alcohol is oxidized by certain bacteria (genus of *Acetobacter*) to acetic acid (The Gardeners and Farmers of Centre Terre Vivante, 2007). Vinegar can be homemade by fermenting fruit juice with sugar and water. A kind of wine is produced first, which subsequently turns into vinegar when it comes in contact with the oxygen in the air (Gravani, 2011). Fruits and vegetables are pickled in a solution of vinegar with a concentration of more than 4 %. The pH should not be lower than 3.5. For preservation white or cider vinegar of a concentration of acetic acid 5 % can be used. The vinegar is a preserving agent, sterilization being unnecessary (Cruess, 2008). The products may not be stored in metal containers, since the vinegar would dissolve the metal from pots (Battcock and Azam-Ali, 1998). A suitable material for pickling is glass or stoneware container. Preserved with vinegar are mainly cabbage, onions, cucumber, etc. and also some kinds of fruits like lemons and olives. After two or three weeks storage in vinegar the products will be ready for use (James and Kuipers, 2003).

4.5.3. Comparison of preservation methods

In Tab. 6 are shown the advantages and disadvantages of the products processed by preserving method. Each of methods is by something specific. To maintain the odor, taste and color are as the best methods heating and preserving with sugar. Products can be stored for months after preserving in jars (Delishably, 2016). However, the products lose their nutritional value. To maintain the nutritional value is the best preservation done by drying and fermentation, according to FAO (2005). Dried fruit is good source of certain antioxidants and has a high motion of beta carotene, vitamin E, little to no fat and contains up to 3.5 times as many the fiber of fresh fruit (Livestrong, 2015). The great disadvantage of dried food is a low content of vitamin C, which has been destroyed by heating and oxidized (HealthyandNaturalWorld, 2013). It seems that the least suitable method is preserving with vinegar. This method should be combined with pickling to increases the shelf life. The products preserved by this method lose the nutritional value, which is one of the most important part of preserved food (James and Kuipers, 2003).

Tab. 6: Advantages and disadvantages of methods

Method	**Advantages**	**Disadvantages**	
Heating	Taste, color, odor	nutritional value, texture	1,6,8
Drying	antioxidants, nutritional value taste	Vitamin C, color, texture	10,11
Preserving with sugar	Soft, color, texture, taste, prevent browning and discoloration	Nutritional value	1,3,9
Preserving with salt	Color, texture	Taste	2,4,6
Fermentation	Healthy , nutritional value, refresh,	Taste, color, odor	3,5
Preserving with vinegar	Taste	color, nutritional value, texture	7,8

1. Barbosa-Cánovas et al. (2003), 2. Battcock and Azam-Ali (1998), 3. Bearma and Kissel (2000), 4. Cruess (2008), 5. FAO (2008), 6. Giangiacomo et al. (1987), 7. James and Kuipers (2003), 8. Leistner (1992), 9. Welbaum (2015), 10. Livestrong (2015), 11. HealthyandNaturalWorld (2013)

5. Conclusions

Available literature sources and electronic information sources to analyze traditional conservation methods of food of plant origin to prevent or reduce the risk of proliferation of microorganisms to a minimum and to prolong the shelf life of plant products was investigated in this study. Collection of information was conducted from specific internet databases such as ScienceDirect, Web of Knowledge and Google Scholar. Key words used were „plant", „preservation" and „food spoilage". It was not so easy to choose which concrete method of all is predominant but generally there are six of the most used traditional preservation methods, concretely heating, drying, preserving with sugar, salt or vinegar and fermentation. Every preservation method is specific for some region because of the wide diversity of food in different areas. The most effective method seemed to be preservation by sugar due to the easy way of application and availability for all tropical and subtropical crops. Such preserved products retain their color and structure and they can be stored for months after preserving in bottles. The second method which was evaluated as the effective one is fermentation. Products preserving by fermentation are healthy, full of nutrients and can be stored for years.

This work brings a complete overview of preservation methods suitable for tropical and subtropical areas. This knowledges could serve as a basic literature review for the writing of diploma thesis which might be focused on specific area and it might examine local methods of food preservation in details.

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