CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Drying of Selected Fish Species in Cambodia

Master's thesis

Prague 2016

Author:

Bc. Nikola Ždímalová

Supervisor:

Ing. Iva Kučerová Ph.D.

Declaration

I hereby declare that the diploma thesis called “Drying of Selected Fish Species in Cambodia” is my work and effort. The data and results were presented obtained during the conduct of the research. Where other sources of information were used, they were appropriately acknowledged in the thesis and are found in the List of References.

....

Date Signature

Acknowledgements

I would like to thank my thesis supervisor Ing. Iva Kučerová, Ph.D for her overall help, patience, relevant comments and guidance. Futher, I would like to thank Ing. Anička Hubáčková and Ing. Miloslav Petrtýl Ph.D., who heleped me during the research. Finally, I am also very thankful to my family and friends.

Abstract

Drying is one of the most commonly used method of conservation, particulary in developing countries, where is still lack of the acces to electricity. This method of preservation can be innovative approach to the problem of food preservation, especially in less developed countries like Cambodia, where majority of inhabitants are depend on fishery and aquaculture. Because of the huge losses, mainly during the storage, there is a need for more developed approach to conservation of fish meat. That is the main reason, why the drying process of fish species Nile Tilapia (*Oreochromis niloticus*), Channa (*Ophicephalus sriatus*), Silver Barb (*Puntus gonionotus*), Walking catfish (*Clarias batrachus*), Pangasius (*Pangasius hypophtalmus*) in different dryers were investigated in this study. For drying in eletric oven (EO), samples of fish meat were divided in two halfs. First half was treated with 3.5% saline solution for one hour and second half were not treated. For drying in hybrid solar dryer (HSD) and greenhouse dryer (GH) all samples were treated also by 3.5% saline solution for one hour. All samples were dried for 16 hours during two days. From the results of this study, it is evident, that GH should be the most suitable method of drying of fish meat in climate conditions of Cambodia. Concretely, the moisture content of Silver barb (SB) samples dried in GH reached the lowest values, which mean, that they were dried the fastest. When we compared unslated and salted samples dried in EO, there was a statistical significant difference ($p<0.05$) between them. Organoleptic properties (appearance, aroma, taste, texture and overall acceptability) of fish samples of boiled and dried fish meat were assessed by the 30 and 24 member degustation panel, respectively. Results of sensory analysis were different in the case of boiled and dried fish samples. The best scored fish form boiled samples was Walking catfish (WC) followed by Nile tilapia (NT). The last part of this study was focused on preferencies of Cambodian people using the questionnarie.

Key words: Drying, solar drying, dryers, drying kinetics, Cambodia, Mekong river, *Oreochromis niloticus, Ophicephalus striatus, Puntius gonionotus, Clarias batrachus, Pangasius hypophtalmus,* organoleptic properties

Table of contents

List of Tables

List of Figures

List of Abbreviations

WC	Walking catfish
CH	Channa
NT	Nile tilapia
PG	Pangasius
SB	Silver barb
GH	Greenhouse
HSD	Hybrid solar dryer
EO	Eletric oven
S	Salted
UNS	Unsalted
MR	Moisture ratio
MC_{db}	Moisture content (dry basis)
MC_{wb}	Moisture content (wet basis)
STD	Standart deviesion
RUA	Royal University of Agriculture
CULS	Czech University of Life Sciences Prague
FAO	Food and Agriculture Organization of the United Nations
UN	United Nations
WB	World Bank

1. Introduction

1.1 Overview of study area

1.1.1 Location, area and geography

The Cambodia (see Figure is located in Southeast Asia, bordering with Thailand, Laos and Vietnam. The total area of Cambodia is 181 035 km^2 (it is devided into 24 distric) and the 159 000 km^2 of this area is around Mekong River (Ditlich, Milik; 2010). The climate is tropical and humid, which is similar as others Asian countries. There are two different season: rainy season (from September to June) and dry (from October to May).
Among the largest freshwater area in Cambodia is Tonlesap Lake, also ranks among the largest lake in Southeast Asia. Permanent water body of Tonlesap Lake is more than 2500 km^2 in the dry season, however during the rainy season surface can multiplied more than fourfold to an impressive 12 000 square kilometers. In late June the monsoon rains brought from the north of the Mekong river water into the river Tonlesap, which will change the direction from the south to the north. During this time the level of the water in the lake rises four to fivefold. Volume of water is increased to fifty times and depth increases from one up to 12m (Osmose, 2013).
The Tonlesap Lake is one of the most important sources of freshwater fish in the world. It is also the biggest natural ecosystem with the presence of snakes and with largest colony of endangered water birds in Southeast Asia (Kuenzer, 2013). Indochinese peninsula and the entire continental area of Southeast Asia has a complex geological and climatic history, which is a result of today's diversity of fish (Kottelat, 1989). At the beginning of the rainy season, water clarity increases. Depth reaches along the Thai-Laotian border almost 15 m and the stream becomes treacherous. Due to rapid changes in the flow of the Mekong River current is very slow down or even reverse the small tributaries called Preki and water from the Mekong spills over to the flood area forests (Rainboth, 1996). The current speed and channel morphology changes; as Mekong River lower the river flows, itis affecting species that favor certain parts of the river. The upper and lower sections of the Mekong River conceals different kinds of fish fauna. The main steam of Mekong River and the lower reaches of tributaries are during the flood season very muddy due to high sediment supply. Lowland flooding of the

Mekong region, including the Great Lake are the main source of Mekong fish production, estimated at least 500 000 metric tons per year (Lagler et al., 1976).

Base 802467 (R02153) 12-97

1.1.2 Economical situation

Cambodia is poorly developed country with low income (WB, 2012). Economic situation was mainly affected by history. In particular of Khmer Rouge occupations but seems to be stabilizing in recent years.

The Gross domestic product (GDP) reached up to 16.78 billion USD (WB, 2014). Cambodia is one of the Association of Southeast Asian Nations (ASAN) members. Human development index (HDI) decreasing to 0.555 and ranked Cambodia to 143 place (UNDP, 2014). The main goods and products, which Cambodia exported are clothes and agriculture products (rubber, tobacco, soybeans, rice and fish).

1.1.3 Agriculture

Agriculture is most priority in Cambodia. Besides rice farming, most people of rural area grow cash crops such as maize, cassava, beans, cashew and raise poultry (duck, chicken) and livestock to supplement daily subsistence and income earning. Forest and fisheries make evenly very important contributions to agriculture and economic. Before 1960 forest covered almost 70% of the total land area (13.23 million ha). The current extent of forest cover is estimated at 59%. Fisheries is after rice considered the second most important sub-system (Bansok et al. 2011).

1.1.3.1 Fishery and aquaculture

The main component of nutrition for the population of Cambodia is fish and fish products, which are an important source of animal protein. Annual fish production is about 514 000 of tons of live production and approximately 470 000 of tons is intended for human consumption. Cambodian annually consume 33.8 kg per person. The average intake of protein from fish is amount to 18.3 g per person and day, which accounts for almost 80 % of animal protein intake (Beran et al., 2007).

The estimated number of fish species in Mekong River is between 758 and 1500. In the whole world, Cambodia has the largest representation of family fish (Beran et al., 2007). Many people depend on the very sensitive ecosystem, and therefore it should be very careful approach, which could help with dealing with the problems in this area. It also should be protected from behaviour of irresponsible fishers (Song et al., 2005). The freshwater capture fisheries in Cambodia are the highest in the whole world. More than half of the provinces in Cambodia is considered as a fishing province and six of them border with Tonhle Sap Great lake (Ahmed et al., 1996). Poor people usually have a reason to eat the whole fish (dried, smoked, fish sauce) (Hortle, 2007).

For Cambodian people are more important inland fisheries more than marine fisheries. According to Try et al, (2001), almost 80 percent of fish production comes from inland fisheries. The agriculture, fisheries and forestry together form around 8% of Cambodian GDP. It also plays very important role in economy, society and has also potential to contribute to poverty reduction and to improve quality of nutrition (Hortle et al., 2004).

In 2007, Cambodia produced an estimated 515 000 tons of fish (see Table 1). Fishing sector employs approximately 420 000 people and more than 2 million people have benefited from the integration in this sector (FAO, 2011).

Table 1. Data of fishery in Cambodia (FAO, 2011)

2007/tons of live weight	Production	Import	Export	The total offer	Offer per capita Kg/year
Fish for direct human consumption	514 200	8037	49361	472 876	33,0

Aquaculture in Cambodia mainly includes cage breeding, rearing fish in ponds and placers. For now, this sectordoes not contribute significantly in the total fish production in Cambodia. However in the future can be expected to increase (improvement of living standards, population growth curve, etc.), which may lead to consequential environmental degradation. The reason is the poor infrastructure, which limits the distribution of fish feed, spawn and industrial products. Channa *(Channa sriata)* was the most important species reared in battery cages. Since 1995 this method of rearing was prohibited, to avoid catching small fish serve as food for predatory snakehead banded. The commercially most popular species kept in battery cages include P*angasiodon hypophthalamus*, *Clarias batrachus* and *Oreochromis niloticus*. In areas where is a demonstrable lack of fish, such as the provinces of Takeo and Kampong Speu (FAO, 2011) are extended small aquaculture focused on common fish species as carp and Nile tilapia.

1.1.3.2 Common fish species

1.1.3.2.1 Nile Tilapia *(Oreochromis niloticus)*

This species, *Oreochromis niloticus* (Linnaeus, 1756) belongs to the family *Cichlidae*, order *Perciformes* (see Figure 1). Because of good qualities of this species such as flexibility to many water bodies in reproduction, or herbivorous or omnivorous diet and adaptability to almost any type of water, tilapia has been considered to be ideal type for aquaculture (Pillay & Kutty, 2005). The interspecific hybrids nowadays are the most common aquaculture species in Asia. An example might be "red hybrids" that arose by crossing two species of *O. mossambicus* x *O. niloticus* (Welcome & Vidthayanon, 2003). According the FAO statistics of aquaculture from 2002 shows that group of tilapia fish are the third largest in production – after carp, salmon and trout (De Silva, 2004). States of ASEAN and China reached in 2002 total production (fishing and breeding) 1 166 737 of tons (Bartley, 2005). Enthusiasm for this kind in recent years is so high that some people call them "aquatic chicken" (Pillay & Kutty, 2005).

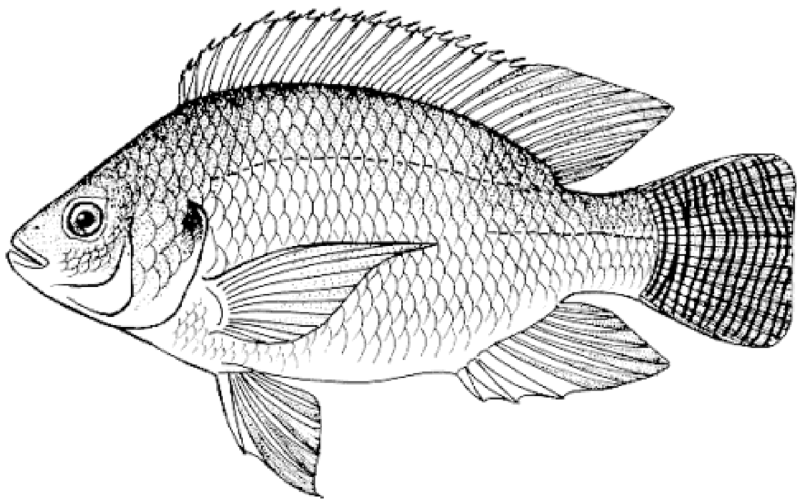


Figure 1. ***Oreochromis niloticus*** **(FAO, 2016)**

Geographical extension

It is concerns a group of fish that was in the last 50-60 years, introduced into water system and aquaculture around the world (Pullin et al., 1982). This group not only contributed to increasing the food supply, but it does become a major species in the inland fish production in Asia, where it has both significant socioeconomic impact on the lives of the rural population (Rainboth, 1996). Nile tilapia (family *Cichlidae*) originally came from Africa (Kitty & Pillay, 2005). In 1930, De Silva (2004) described the first shift of the tilapia species on the Asian continent. Type of tilapia *Oreochromis mossambicus* was brought into Indonesia from southeastern Africa. Rainboth (1996) described the expansion of this kind in Thailand. Currently it consist of these species in the Mekong River Basin wild population, mainly along the Thai-Laotian border. Even the perception is that their expansion would affect the collapse some of the traditional ways of catching fish, and even endangered catching local fish species (Gindelberger, 1981).

Biology and Morphology

Tilapia belongs to the species with the ability to reproduce almost any aquatic environment. Breeding of Tilapia is very advantageous because it is an omnivorous species that is relatively easy to feeding (Pillay & Kutty, 2005). It feeds on mainly with phytoplankton, including diatoms and bacteria as well as in sediments. They have long spiral casing up to fourteen times the length of the body (McConnell, 1959). The size of an individual can be up to 46 cm (Rainboth, 1996). On the dorsal fin has a total of 15 to 18 hard rays and 11 to 13 soft rays. The anal fin has 3 hard soft rays and 9 to 11 soft one. Tilapia has 30-32 vertebrae. The adult jaws are magnified and it means that the length of the lower jaw reaches 29-37% head length. Genital papilla mating females are not frayed. The most distinct features are regular vertical stripes along the entire length of the tail fin. It is an oviparous species. For Tilapia, there are two ways to care for offspring. In the first case, fish nests on the bottom of water bodies into which they subsequently spawn. In the second case breeding fertilized eggs are male or female in the oral cavity (Pillay & Kutty, 2005). Bailey (1994) described the occurrence of tilapia in different freshwater environments such as rivers, lakes, wastewater and irrigation canals. This is mainly on the daily fish that tolerate temperatures between 8-42° C. the optimum breeding temperature ranges from 13.5 to 33 ° C (Philippart & Ruwet, 1982).

1.1.3.2.2 Walking catfish *(Clarias batrachus)*

Another representative of freshwater fish in floodplains is a species of *Clarias batrachus* (Linnaeus, 1758), which belongs to the family *Clariidae*, order *Siluriformes* (see Figure 2). Among the more frequently used designation by FAO include the name "walking catfish", local fishermen know him as the "trey anhinga roueng" (Rainboth, 1996). *Clarias batrachus,* is one of the most important farmed catfish aquaculture in Asia (Pillay & Kutty, 2005). In South Asian countries, this specie is the most important representative of a group known as "live fish", which is the collective name for a group of fish with respiratory organ enabling them to breathe atmospheric oxygen and survive for long periods out of the water in marshy areas (Pillay & Kutty, 2005).

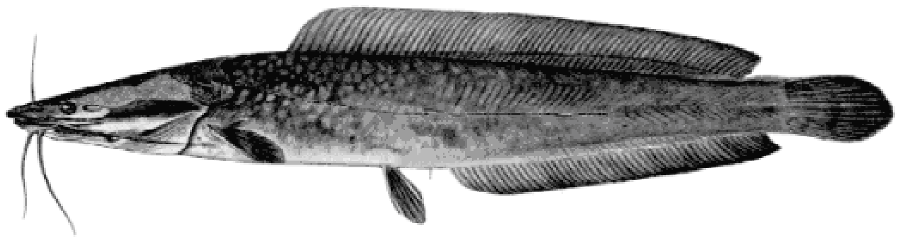


Figure 2. ***Clarias batrachus*** **(FAO, 2016)**

- Geographical extension

According Reinbothe (1996) Walking catfish is extended from Sri Lanka, Indonesia and Philippines. Other sources indicate that catfish belonging to the family *Ictaliridae, Pangasidae* and *Siluridae* are widespread in various parts of the world and breeding of these species has become traditional is some parts of southeast and south Asia (Pillay & Kutty, 2005). In eastern India and Bangladesh are reclaimed swamp used for keeping together several species of fish and other species, such as *Hetoropneustes fotilis, Anabas testudineus* and channa spp. (Pillay & Kutty, 2005). Thailand has the highest production of Walking catfish and it also applies to research work related to its breeding. The considerable part of research has been carried out in India and the

Philippines, where the most important Asian species are *Clarias macrocephalus* and *Clarias batrachus* (Stickney, 2000).

The Walking catfish is most important and popular species as a major food source of many tropical regions. In European countries is bred in recirculating water system (Stickney, 2000).

- Biology and Morphology

Walking catfish was studied with zoologists for his ability to survive a long time without water due to direct breathe atmospheric oxygen. This species normally grows to a length of 40 cm and lives in stagnant water or slow flowing rivers. Commonly occurs in floodplains and flooded forests (Rainboth, 1996). Walking catfish was named for its ability to use the pectoral fins amended know as elbows which facilitate his movement on land (Pillay & Kutty, 2005). The physiological and morphological adaptation allow the fish to survive aestivation that bury into the mud or leaves the reservoir, which dried up to find another sources of water. Often they eat fish and shellfish (Stickney, 1996).

The Catfish are very well adapted to the environment, in which they occur due to the very sensitive hairs that help concentrate food without the use of the eyes (Valbo-Jørgensen et al., 2009). Their resistance to adverse conditions and the ability to survive long periods out of water are mainly in tropical countries big advantage. In some areas of eastern India exist for this kind of fish (life fish) special markets (Pillay & Kutty, 2005). Like other freshwater catfish also this species does not have tolerance to salinity. They are omnivorous, aggressive and they discussed the possibility of cannibalism (Stickney, 2000).

1.1.3.2.3 Channa *(Channa sriata)*

Channa sriata (Bloch, 1795), belonging to the family *Channidae,* order *Perciformes*, is another generic deputy investigated in this research (see Figure 3). Sometimes is referred to as *Ophicephalus striatus* and FAO is referred to as “chevron snakehead”. In Cambodia local conditions, is known as “trey raws” (Rainboth, 1996). “Murrels” or snakehead belongs to the highly coveted food source in South and Southeast Asian countries (Pillay & Kutty, 2005).

Geographical extension

Although snakehead bred in many Asian countries, their farms have not yet reached the main commercial importance (Pillay & Kutty, 2005). They are most often spread from Sri Lanka, Indonesia, the Philippines and China. It is one of the most common snakehead in Cambodia (Rainboth, 1996). In tropical Asia, there are more than 30 kinds of snakehead, the incidence was also reported in northern China and Africa. For aquaculture are important species *Channa* (*Opicephalus striatus*, C. *marulius*, C. *punctatus*, C. *maculatus* and C. *micropeltes)* (Pillay & Kutty, 2005).

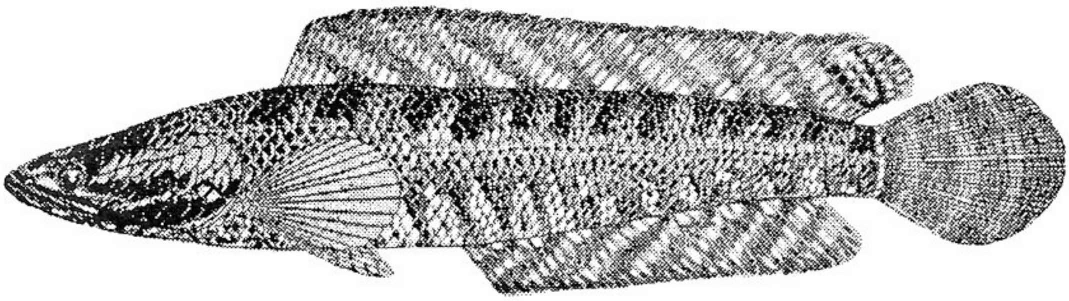


Figure 3. ***Channa sriata*** **(Courtenay et. al. 2004)**

- Biology and Morphology

For their ability to breathe atmospheric oxygen may be viable for a long time kept the markets in containers. Their taste and texture of the flesh is ranked as suitable species to feed disability and convalescent patients. *Channa Sriata* grows to the size of 1-1.2 m. These individuals are highly resistant and endure adverse conditions. If they are kept moist, they can survive outside of the water for a long time. Also in the dry season, called summer sleep, which lasted several months, they are buried in the mud. The optimum temperature for survival is between 25-30°C.

They are very sensitive to sudden changes in pH, but can live in acidic and alkaline waters and come in slowly flowing or stagnant waters (Rainboth, 1996). It is a freshwater species, but they are viable even under conditions of moderately saline brackish waters. In Cambodia and Vietnam snakehead commonly grown in battery cages along the coast or are placed in cages behind a fishing boat. It belongs to the species, which are characterized by the characteristic ferocity and cannibalism.

Snakehead usually grow in monocultures (Pillay & Kutty, 2005).

1.1.3.2.4 Silver barb *(Barbodes gonionotus)*

Barbodes gonionotus (Bleeker, 1850), belongs to family *Cybrinidae,* order *Cypriniformes*. Species of Silver barb has a many of latin synonyms *(Barbodes jolamarki, Barbus gonionotus, Barbus javanicus, Barbus koilometopon, Puntius gonionotus, Puntius javanicus, Puntius jolamarki, Puntius viehoeveri)*, but *Barbodes gonionotus* (see Figure 4) is currently valid name (Rainboth, 1996).

- Geographical extension

This specie is commonly found from the border of Thailand to Indonesia. It is commonly found at midwater to bottom depths in rivers, floodplains, streams and occasionally in tanks. It is obvious that this fish prefer rather standing water compared to the flowing waters (Rainboth, 1996).

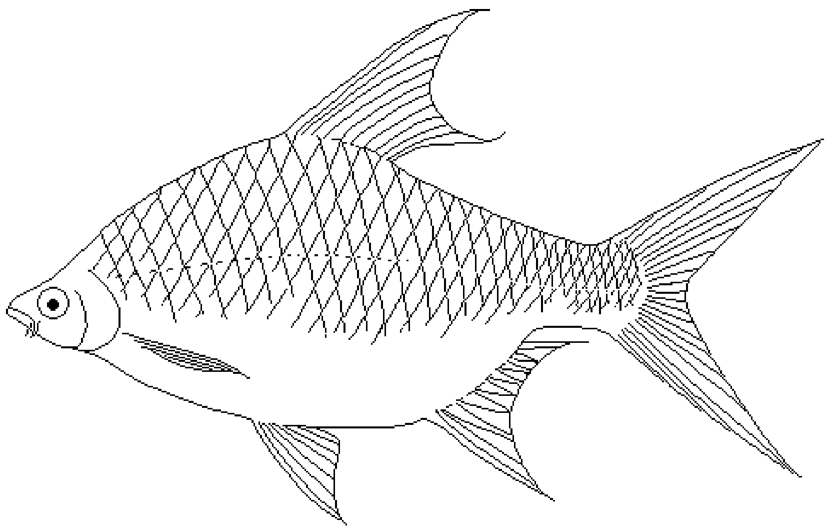


Figure 4 Silver barb (FAO, 2016)

Biology and Morphology

Silver barb, small fish with maximum size reaching 33 cm is commonly feed on plant matter (e.g weeds, leaves *Ipomoea* reptans and *Hydrilla*) and invertebrates (Rainboth, 1996). They belong to the migratory species, but not considered to be a long-distance migrant. It is known as a local migrant, which moves from the Mekong River up into small steams and during the rainy season in flooded areas and back again during receding water. Some records indicated, that upstream migration of fish triggered by the first rain and rising water levels (Song, 2005). When the fish finds a canal, steam or tributary it moves upstream and ultimately onto flooded areas. During the retreat of the water, Silver barb moves back into the canals, rivers, streams and also into the Mekong River. (Welcome, 1988).

1.1.3.2.5 Pangasius (*Pangasianodon hypophthalmus*)

This species *Pangasianodon hypophthalmus* (Sauvage, 1878) belongs to family *Siluriformes*, order *Pangasiidae* (see Figure 5). According to FAO Pangasius can be also known like “Striped catfish”. In Cambodian local conditions is known as Trey pra (Rainboth, 1996).

- Geographical extension

Pangasius is an omnivorous fish, found in large rivers of the Mekong and Chao Phrya basins. Now this species is widely introduced for aquaculture. Pangasius is feeding with fish and crustaceans and also with vegetable debris (Rainboth, 1996). They are migratory species which move from the upstream Mekong to spawn there during May-July and returning to the mainstream when the river waters fall seeking rearing habitats in September-December (Hill, 1994). Commonly found in the lower reaches of the Mekong River, where the young fish are collected into floating cages for breeding. In the middle of the Mekong Pangasius is represented by large individuals that lose the dark coloration of juveniles and subadults and become grey without stripe (Rainboth, 1996). Pangasius is one of the most important aquaculture fish species in Thailand (Roberts, 1993).

- Biology and Morphology

*Pangasianodon hypophthalmus*can grow at least to 120 cm. The body is long and laterally flattened without scales. Pangasius has relatively small head, but the mouth has wide with tiny sharp teeth. Eyes are relatively large. Fins are stained in dark grey or black. Young fish of Pangasius are characterized by having a black stripe along lateral line and another long black stripe below lateral line. This species has been brought into the aquarium trade where its generally non-aggressive behaviour is valued in community tanks. It requires a great deal of space and is not suited to small privately owned tanks (Rainboth, 1993).

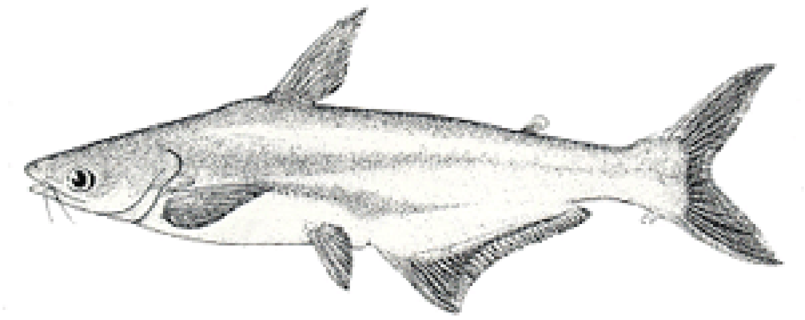


Figure 5. ***Pangasianodon hypophthalmus*** **(FAO, 2016)**

1.2 Conservation methods of fish meat

1.2.1 Salting

The salting, alternatively called curing, is one of the oldest method of preservation of fish. Salting is used as a single step for preservation of fish or as a pretreatment before drying. Both fatty and lean fish species can be salted, though methods of salting vary for fatty and lean fish species. As a pretreatment, salting is the most common process and it is used for pretreating fish species for drying and smoking. According on type of fish, desired form and final product characteristics, technological advancements and regional variations, number of salting methods are evolved over the period of time (Jangam et al, 2011).

During the process of salting the fish species are kept in contact with salt solution or dry salt. Over the period of time, salt penetrates into fish tissues, moisture comes out and tissue cells shrink. Both these processes generate adverse conditions for microbial growth. Salting acts as preservative method and also it provides flavor and sensory analysis (Rahman, 2007).

1.2.1.1 Methods of salting

Firstly, fish must be cleaned before beginning of salting process. Depending on desired form of final salted fish species can be salted entirely or it can be beheaded, spit, skinned, filleted or deboned. There are many options for preparing fish species for salting. Fish can be washed and cleaned before further processing. Salting can be classified in two categories:

- Drying salting
- Brine salting

1.2.1.1.1 Drying salting

Over time progresses, moisture comes out and creates brine. Depending upon whether self brine of fish species is drained out or not, dry salting is futher classified. In the case of fatty fish is important, that the fats undergo to oxidation due to atmospheric oxygen and it creates rancidity. To prevent rancidity in fatty fish it is necessary to care of contact fish with air is avoided. After some time, it can be many hours but also days, the fish are taken out, laid in stacks to press out water and processed further. Salt absorption is not uniform throughout the fish in the case of dry salting (Jangam et al, 2011).

1.2.1.1.2 Brine salting

The brine salting is also called wet salting method, in which fish samples must be immersed for some time in salt solution. This treatment is used mainly for fatty fish. Fish remains soaked in brine without any contact with air. Brine salting can be classified as hard curing and light curing. This depends on salt percentage in final dried fish. Light curing is more popular because of better organoleptic properties. Italso produces lower salt content fish. Hard curing produces salted fish with salt content up to 30% (Ronsivalli and Learson, 1973).

1.2.1.2 Parameters of processing

1.2.1.2.1 Temperature

Increase in salting temperature raises salting rate. During the drying process, the microorganisms are still present and the temperature may enhance their growth leading to spoilage. To prevent spoilage, the temperature should not raise to take advantage of higher salting rate. Even if the selection of temperature is arbitrary, low temperatures and also brine made from ice are preferred during salting in temperature range of 0°C to 38°C (Rahman, 2007).

1.2.1.2.2 Fat content

Fats, which occurs in fish get oxidized by atmospheric oxygen and produce rancidity. Depending on the type of fish (fatty or lean) salting should be chosen. As fat content increases in species, salting rate decreases. But total salt content intake in final dried fish is lower in lean fish and more in fatty fish. Therefore it may happen for fatty fish samples salting rate and salting times are low and total salt intake is low as well (Jangam et al, 2011).

1.2.1.2.3 Salt concentration

The salt concentration decides osmotic pressure, which is created by brine and it also decides about moisture removal rate and salt uptake rate. It is known, that the salt concentration is higher, when the degree of salting is higher. However, this may also lead to uneven distribution of salt in fish. Therefore it should be chosen an appropriate salt concentration, which determined with respect to the final salt content, preservation, desired organoleptic properties, uniform salting and salting time (Jangam et al, 2011).

1.2.1.2.4 Salting time

Salting is carried out after equilibrium is established, but if it is used as salting pretreatment, one does not rely on preservation. In these cases, salting time can be reduced. Temperature, fish species, salt concentration, thickness of fish samples and rest of the parameters together determines salting time (Jangam et al, 2011).

1.2.1.2.5 Final moisture content

In salting, moisture content in final product and salt content decides preservation. Therefore, for longer durability is necessary to use a higher content of salt in the products. It is known, that the final moisture content depends on whether salting is the just preservation or it’s a pretreatment for further preservation (Jangam et al, 2011).

1.2.2 Smoking

Similarly, in case of any meat, also fish can be smoked by cold or hot smoking. Fresh fish for cold smoking should be rid of the brining of the water and leave theme there ferment so as to be almost right to use. Therefore, the pickle must be relatively concentrated, generally about 16% (Kyzlink, 1988).

1.2.2.1 Smoking principle of preservation

Wood smoke is a complex combination of volatiles. Fish species exposed to the smoke, which can be preserved by following principles:

a) Dehydration: partial dehydration of fish occurs during the smoking.
b) Smoking: Smoke can contains different volatiles, which contain bacterial and antioxidants compounds. Smoke imparts flavour and color to smoked product (Jangam et al, 2011).
c) Cooking: During hot smoking, fish product is cooked approximately about 63°C, which is leads to reduction in microbial count (Rahman, 2007).
d) Pretreatment: salting is sometimes used as pretreatment for smoking. The equilibrium of salt is reached during smoking process and salting acts as additional preservative step (Jangam et al, 2011).

1.2.2.2 Methods of smoking

For smoking on border basis, steps those are followed are enlisted (Ronsivalli and Learson, 1973):

a) Preparation: This part is depending of fish species. Viscera is removed, fish is scaled, beheaded, split, filleted or cut and finally washed.
b) Pretreatment: Before smoking fish can be lightly salted.
c) Fish form: For smoking can be used fishes, which are beheaded, split or filleted.
d) Prior drying: After salting, fish is washed and dried under the open sun or in dryer.
e) Smoking: mainly divided between two types: hot smoking (partially dehydrated along with cooking at 70 - 80°C and cold smoking (carried out at temperature below 38°C)

f) Storage: The product, which are smoked are rapidly cooled at refrigeration temperature and stored in that condition. In the case of dehydrated and hard smoked product can be stored at room temperatures (Jangam et al, 2011).

1.2.3 Drying of fish meat

Drying is the oldest method of preserving. The methods of drying which is mainly used in combination with salt are most popular (low cost fish preservation techniques). In developing countries due to its low processing and storage cost, drying of fish species are preferring. Fish are usually dried under open sun at atmospheric conditions. For processing fish under controlled and hygienic conditions may use mechanical dryers. These dryers also include solar dryers. Vacuum, freeze and heat pump dryers are being used with specific applications, which given better quality of dried fish samples (Jangam et al, 2011).

1.2.3.1 Quality of products

During the drying of meat, evaporation of water and weight losses cause changes of the shape of the meat, because of shrinkage. The meat pieces get smaller, thinner and also wrinkled and darker in color. The changes are also in texture – from soft to firm to hard. Appearance, taste and processing properties of dried meat are not longer comparable with fresh meat. In some cases, in particular absence of refrigeration, these disadvantages have to be tolerated. Mainly because of possibility, that meat get spoiled or contaminated. Most nutritional properties of meat, in particular the protein content, remain unchanged through drying (Heinz and Hautzinger, 2007). Food safety is a top priority for authorities and consumers worldwide. Food safety objectives and hazard analysis and critical control point are being introduced worldwide. Adequate preservation technologies must be applied (Aymerich et al., 2008). Solar drying is an option.

1.3 Drying

Drying of food is the most common methods, which is used for preserving food. All of foods variety in our day requires some form of preservation, mostly to reduce or stop spoilage and to make it available during the year. This method trying to help people to be less dependent on daily food supply. Drying is primarily used to protect food against deterioration, which is caused by microorganism and against pathogenic bacteria (Chen, 2008). Amongst these, spoilage is the foremost reason for employing food preservation techniques. Spoilage or deterioration of food occurs during handling or due to mechanical, physical, chemical or microbial damage. Out of these, chemical and microbial damages are most frequent causes (Rahman, 1999). The dehydrated foods industry has a prominent place among today's food industries all over the world, specifically in developing countries (Vega-Gálvez, 2011). The main important effect of drying is to reduce water activity in the dried foods to prevent the growth of microorganisms. However bacterial inactivation and enzyme that accompanies heat-based drying methods has both adverse and beneficial effects, depending on what biological material is processed. In the case of foods, the aim is usually to maximize microbial inactivation and enzyme. On the other hand, when drying bacterial cultures, vitamins or enzymes, we seek to achieve little to no inactivation (Rahman, 2007). Selection of dryers for food products is itself a complex step. There are hundreds of dryers available and more than one dryer can suit a particular application. In developing countries food products are dried mainly by open sun drying. Anyway this method is still common at many places for non-commercial use. There have been numerous efforts to develop advanced drying methods for commercial scale or food products (Kudra and Mujumdar, 2009). The conventional method for dehydrating food products is heating air using a flue gas or an electric heater. As regard of a flue gas method, the heat transfer occurs mainly through convection. In chiefly, the selection of heating methods influences greatly both quality of drying energy cost and such as a significant aspect of the drying (Rahman, 2007).

1.3.1 Drying fundamentals

During the thermal process of drying a wet solid occurs two processes:

- In first process heat is transformed into change of the temperature of the wet solid and to evaporate surface moisture.
- In the second process, the mass of transfer to the surface of the solid an then evaporated into the atmosphere (Mujumdar, 2006)

Drying is a complex operation involving transient transfer of heat with using several processes, such as physical, chemical and biochemical transformations, which of course may cause a change of the quality of products. Physical changes can also result in changes in mechanisms of mass transfer and rates of heat transfer within the material. In the context of physical changes, that may occur during drying contain: puffing, shrinkage, glass transitions and crystallization. Among others, in some cases it may leads to a chemical or biochemical reaction that allows changes to the texture, color and other properties (Mujumdar, 1997)

1.3.1.1 Thermodynamic properties

Psychometry

Most of dryers are direct type, in which the hot air is used to supply the heat for evaporation and also carries the evaporated moisture out of the product. Drying with heated air implies humidification and cooling of the air. Consequently, hydrothermal properties of humid air are required for the design calculation of dryers. Table 2 shows a list of definition of various terms that occur during drying and psychrometry. (Mujumdar, 1997).

Table 2. Definition of commonly encountered terms in psychrometry and drying (Mujumdar, 1997)

Term/symbol	Meaning
Adiabatic saturation temperature, T_{as}	Equilibrium gas temperature reached by unsaturated gas and vaporizing liquid under adiabatic conditions. (Note: For air/water system only, it is equal to the wet bulb temperature (T_{wb}))

Bound moisture	Liquid physically and/or chemically bound to solid matrix so as to exert a vapor pressure lower than that of pure liquid at the same temperature
Constant rate drying period	Under constant drying conditions, drying period when evaporation rate per unit drying area is constant (when surface moisture is removed)
Dew point	Temperature at which a given unsaturated air-vapor mixture becomes saturated
Dry bulb temperature	Temperature measured by a (dry) thermometer immersed in vapor-gas mixture
Equilibrium moisture content, X^*	At a given temperature and pressure, the moisture content of moist solid in equilibrium with the gas-vapor mixture (zero for non-hygroscopic solids)
Critical moisture content, X_c	Moisture content at which the drying rate first begins to drop (under constant drying conditions)

Table 3. (Continued)

Humidity, absolute	Mass of water vapor per unit mass of dry gas (kg kg^{-1} or lb lb^{-1})
Humidity, relative	Ratio of partial pressure of water vapor in gas-vapor mixture to equilibrium vapor pressure at the same temperature

Unbound moisture	Moisture in solid which exerts vapor pressure equal to that of pure liquid at the same temperature
Water activity, a_w	Ratio of vapor pressure exerted by water in solid to that of pure water at the same temperature.
Wet bulb temperature, T_{wb}	Liquid temperature attained when large amounts of air-vapor mixture are contacted with the surface. In purely convective drying, the drying surface reaches T_{wb} during the constant-rate period.

Psychrometric chart (Figure 6) for air water system describes the relationship between temperature (abscissa) and absolute humidity (ordinate in g water per kg dry air) of humid air at one atmosphere pressure over 0° to 130 °C**.** According to thermodynamic definitions of these terms are drawn lines, which are representing the percentage of humidity and adiabatic saturation (Mujumdar, 1997). Temperature in the moment, when the air becomes saturated with moisture (100% relative humidity) and any further cooling from this point results in condensation of water from the air is called dew point. Theparallel straight lines represent adiabatic cooling lines, which exhibit moisture decreasing with increasing air temperature (Fellows, 2000).

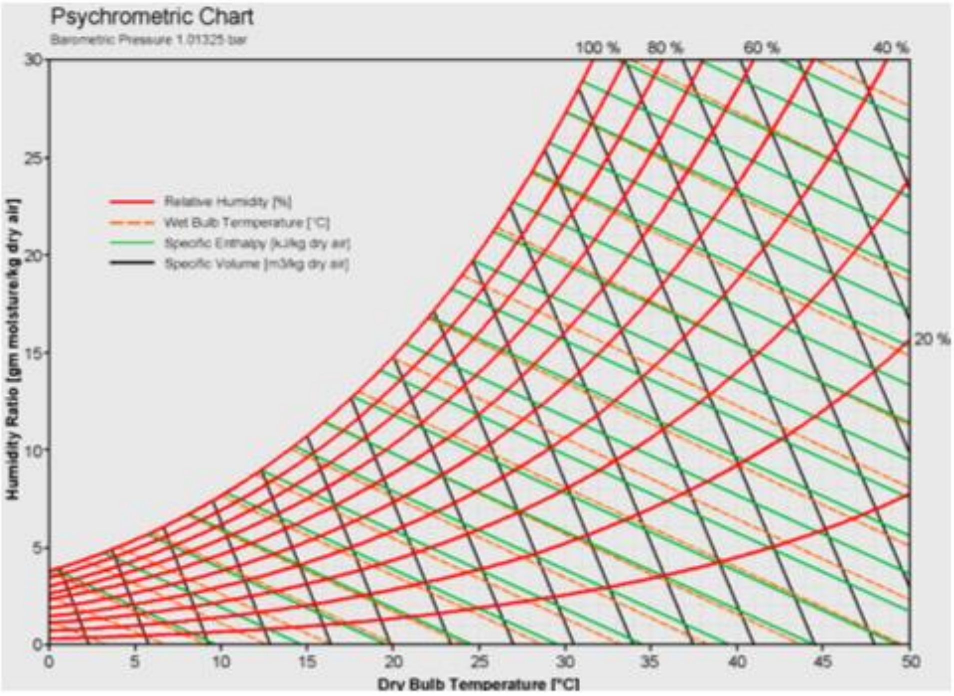


Figure 6. Psychrometric chart (ECCA, 2005)

Equilibrium moisture content

The equilibrium moisture content is the moisture content of wet solids in equilibrium with air of given humidity and temperature. A plot of equilibriummoisture content at a given temperatureversus relative humidity is termed as sorption isotherm. Isotherms, which are obtained by exposing the solid to air of decreasing humidity gives the adsorption isotherm. Most drying materials display “hysteresis” in that two isotherms are not identical (Mujumdar, 1997). As it is shown in Figure 7, the general shape of the typical sorption isotherm. There are recounted three zones A, B and C, which are indicative for various water mechanisms at individual sites on the solid matrix. Water in the area A is tightly bound to the sites. In the area B, water is more loosely bound and in the area C, water is more loosely held in bigger capillaries (Mujumdar, 1997).

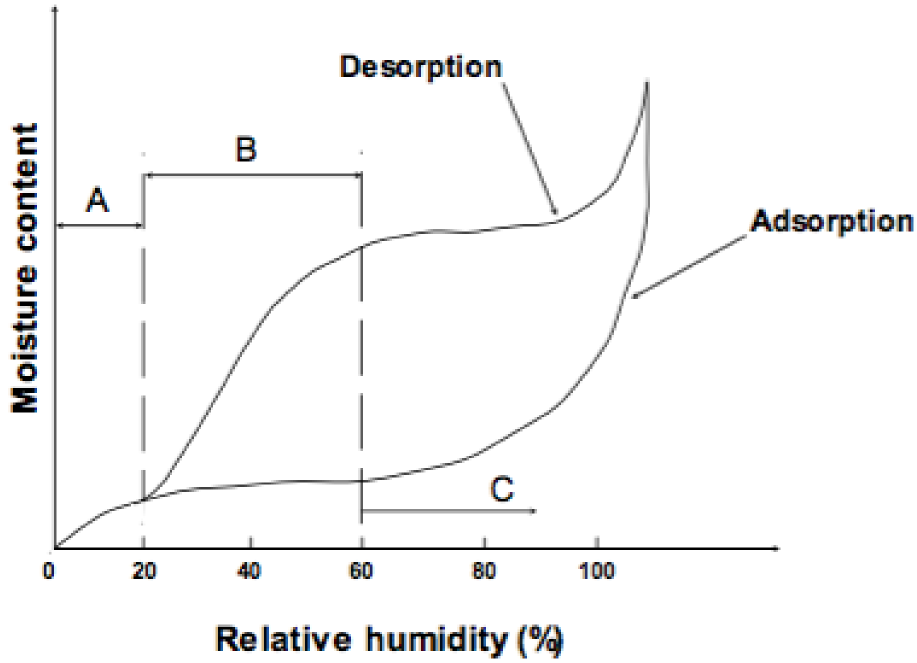


Figure 7. Typical sorption isotherms (Mujumdar, 1997)

1.3.1.2 Drying kinetics

The drying kinetics links the immediate transfer of heat and moisture content with external and internal parameters of the drying. External drying parameters include temperature and humidity and the heat transfer coefficient and mass. The dry-basis moisture content *X*, decreases with time *t*. This is followed by a non-linear decrease in *X* with t until, after a very long time, the solid reaches its equilibrium moisture content, *X** and drying stops. As regards the free moisture content, defined as (Mujumdar, 1997):

$$X_f = (X - X^*) \quad (1)$$

the drying rate drop to zero at $X_f=0$

By convection, the drying rate, N, is defined as:

$$N = -\frac{M_s}{A}\frac{dX}{dt} \quad or \quad -\frac{M_s}{A}\frac{dX_f}{dt} \quad (2)$$

under constant drying conditions (Mujumdar, 1997).

N means the rate of evaporation of water ($kg.m^{-2}.h^{-1}$), A which is mean evaporation area and M_s is the mass of bone dry solid.

If N is plotted versus X (or *Xf)* is so-called drying rate curve. This curve is always obtained under constant conditions.

Figure 8 illustrates the drying rate curve. This curve shows an initial period of constant rate, where $N = N_c$ = constant. The constant rate period is controlled by the rates of the external heat and mass. For the material, which is being dried, the drying period is almost independent. Many agricultural products and foods do not show a constant rate at all since mass transfer rates and internal heat determine the rate at which water becomes available at the exposed evaporating surface. The drying rate remains constant period as long as a film of free water present on the surface. When water cannot migrate to the surface at rate of N_c, N rate starts to decrease at $X = X_c$. The mechanism underlying this phenomenon depends on drying conditions and also on material. The surface, which is being dried firstly becomes to be partially unsaturated and after that fully unsaturated until it reaches the equilibrium moisture content X^* (Mujumdar, 1996).

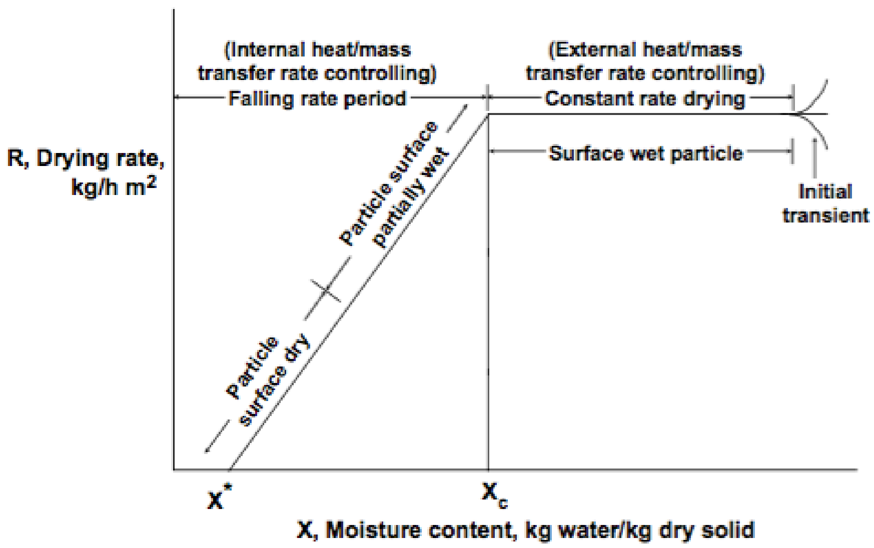


Figure 8. Drying rate curve under constant drying conditions (Mujumdar, 1997).

1.4 Sun and solar drying

In earlier times solar drying was only one way how to dry foods. The most common methods of drying is to spread the crops on a surface expository to the sun (Heindl, 2000). In this process, all materials must be prepared for drying laid on the ground or hanged in the air, where it is exposed to direct sun light. One advantage of solar drying is that it uses a renewable energy source. Although drying in the sun is one of the cheapest but also the least demanding way to get dry foods can lead to a lot of disadvantages. The most essential disadvantages include contamination from the environment or by bad odour, insects and birds. The material that is exposure to direct sunlight can destroy the color, vitamins and flavor. Other disadvantage can be the temperature rises without regulation. In case of rain or watering dew need further drying if mold growth are to be avoided during storage. Drying under the sun may take 2-14 days (De Guzman and Siemonsma, 1999).

Solar drying uses radiant energy from the sun but unfortunately has not yet widely commercialized. Solar dryers are device of small capacity, which based rather on empirical and semi-empirical data than in theoretical designs. The majority of solar dryer are used in large part for drying of various crops either for family use or for small-scale industrial production. One of the main reason why we use of solar drying does not produce any pollution and uses a renewable energy source, which is very rich and cannot be monopolized. The advantages of solar drying include a lower risk of contamination of insects and microorganism, than during open-to-sun drying. Solar drying is one of the most popular methods, especially in developing countries (Rahman, 2007).

1.4.1.1 **Classification of solar dryers**

Brenndorfer (1985) or Ekechukwu (1999) reported two generic groups, solar-energy dryers can be identified, active or forced-convention solar-energy dryers and passive or natural-circulation solar-energy dryers. Also can be identified three-sub groups, integral-type (direct mode), distributed-type (indirect mode) and the mixed-mode type. The only difference of these sub-classes is in the design arrangement of system components and the mode of utilization of the solar heat (Rahman, 2007).

1.4.1.2 **Active solar dryers**

Active solar cabinet dryers (Figure 9) which are also called hybrid solar dryers or forced convection providing modified airflow, temperature and humidity regardless of climatic conditions. These features, connected with the restriction of the bulk depth substantially improve the reliability ofthe dryers in comparison with the natural convection dryers which provide much less opportunities of control, resulting in lower effectiveness (Weiss, 2003).

The use of hybrid solar dryers can mean a reduction in drying time by three times and required space can decrease by 50 %. Hence it is possible that the convection dryers achieve equality of natural convection dryers with collector six times larger. Fans can be powered by electricity, which can be made for using photovoltaic panel, if utility electricity is unavailable. Almost each types of natural convection dryers can be controlled by forced convection (Weiss, 2003).

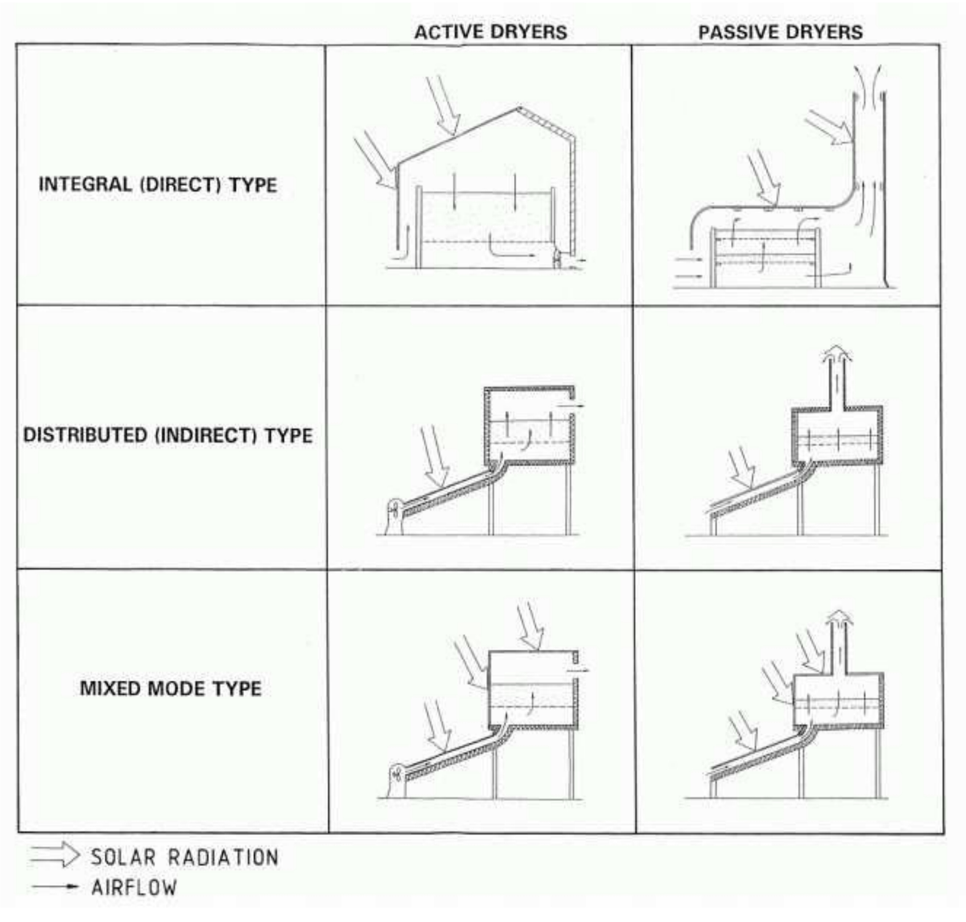


Figure 9. Classification of solar dryers (Weiss, 2003)

1.4.1.3 Passive solar dryers

Passive solar dryer, which are also called natural convection system or natural circulation are operated by solar energy. This energy is used for heating the air, which is then circulated through the material by wind pressure, either buoyancy forces or combination of both. The size of natural convection systems allows for them to be used on farm. Can be divided in direct (tent and box dryer) and indirect (cabinet dryer) system (Weiss, 2003).

2. Objectives

2.1 Main objective

The main objective of this work was to investigate the influence of drying behavior with respect to drying technology and drying pretreatments and sensory properties of selected fish species: Nile Tilapia (*Oreochromis niloticus*), Channa (*Ophicephalus sriatus*), Silver Barb (*Puntus gonionotus*), Walking catfish (*Clarias batrachus*), Pangasius (*Pangasius hypophtalmus*) common in Cambodia.

2.2 Specific objectives

i) Investigation of three different drying methods: a) hybrid solar dryer b) greenhouse dryer and c) electric oven

ii) Evaluation of drying behavior of different fish species meat with respect to used drying technology and its comparison.

iii) Comparison of influence of different processing of fish meat and different fish species on final sensory properties such as appearance, aroma, taste, texture and overall acceptability.

iv) Analysis of preferences of Cambodians in relation to consumption and preparation of fishes in the form of questionnaires.

3. Materials and Methods

3.1 Site description

Research was done at Royal University of Agriculture (RUA) in capital city of Cambodia, Phnom Penh. The city is situated in the Kandal province in the south of Cambodia (see Figure 10). The main part of data was obtained during summer school named “From net to spoon” held in August 2015 within the Czech Development Agency project no. 09/2014/06. The summer school was under supervision guidance of Ing. Miloslav Petrtýl, PhD. Part of summer school was focused on drying fish species in Cambodia.

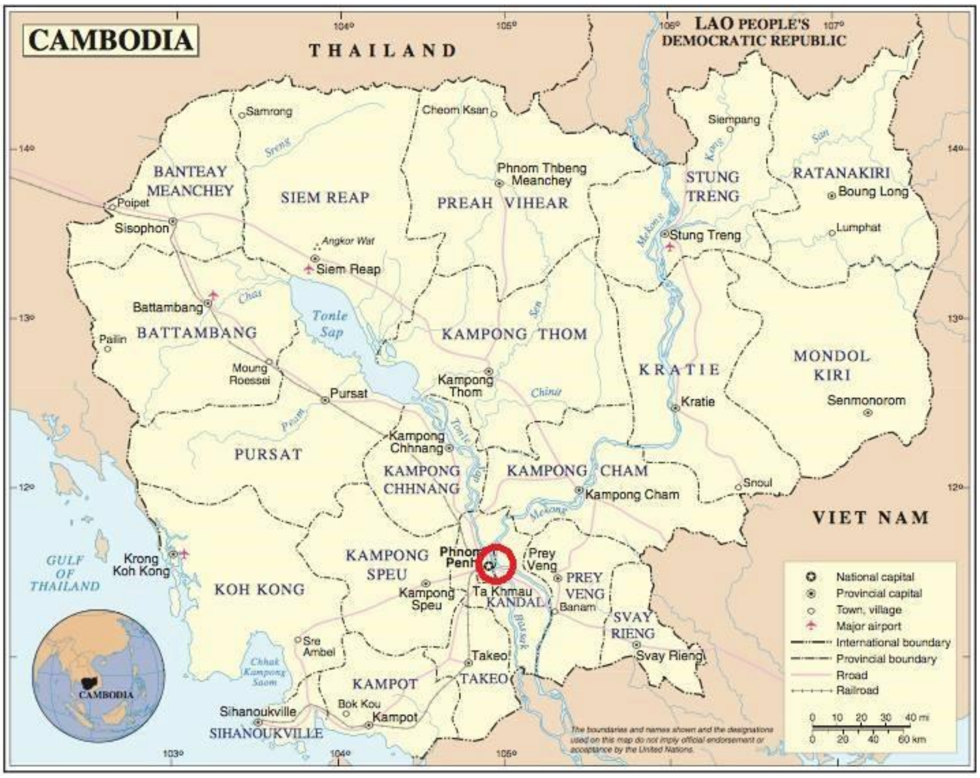


Figure 10. Map of Cambodia (UN, 2004)

Climate of the area is tropical monsoon. There are two different seasons: the rainy and dry. Approximately from October to May comes the northeast monsoon, which brings cold and dry. In the rest of the year the climate affects the southwest monsoon heavy rainfall. The average annual rainfall ranges from 700 to 1500 mm. On the territory of Cambodia, the minimum temperature differences during the year, the average temperature reaches 27°C (WB, 2012).

3.2 Fish samples

Five different species of freshwater fishes were bought on local markets in Phompenh (Cha Ampouv market, Charmka Doung market, Beoung Tompon market and Boeung Trobek Plaza market), which are located near to RUA. Nile Tilapia (*Oreochromis niloticus*)- NT, Channa (*Ophicephalus sriatus*)- CH, Silver Barb (*Puntus gonionotus*)- SB, Walking catfish (*Clarias batrachus*)- WC, Pangasius (*Pangasius hypophtalmus*)- PG were investigated in this study. Fishes were immediately cleaned and sliced in to 10 grams' samples at approximately 50 by 20 mm. Further each fish species samples were treated with 3.5 % saline solution for one hour. After salting all samples were immediately dried in three different dryers. Only in case of electric oven part of each fish species samples were without any treatment and served as a control samples.

3.3 Drying facilities

This research was carried out in three different types of dryer: greenhouse dryer (GHD), hybrid solar dryer (HSD) and electric oven (EO). These types were chosen because they are most popular in Cambodia, mainly because of funding options to local people. The control drying was performed in electric oven (UFE 500 type Memmert, Germany), under constant temperature 50°C and stable air relative humidity 24.2%. The other experiment was conducted in greenhouse dryer (see Figure 11.A and 11.B) and in hybrid solar dryer (see Figure 12.A and 12.B). GHD was constructed by project SHARE in 2014. It was made by combination of aluminum and hardened plastic. HSD was made fully from metal in 2013.

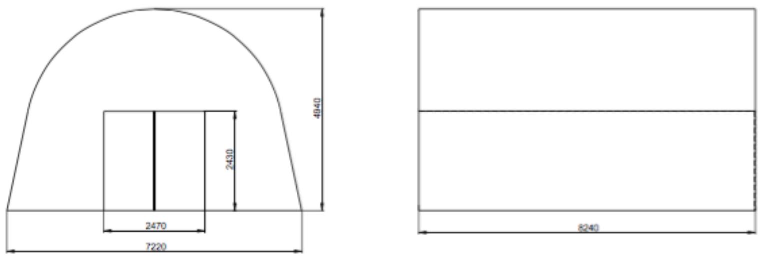


Figure 11.A Schematic illustration of greenhouse dryer (GHD)

Figure 11.B Picture of greenhouse dryer (GHD) (Source, Nikola Ždímalová, 2015)

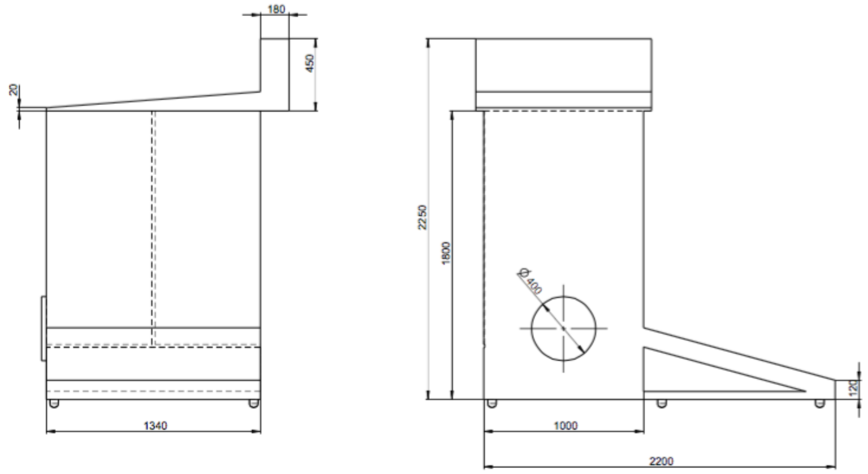


Figure 12. A Schematic illustration of hybrid solar dryer (HSD)

Figure 12.B Picture of hybrid solar dryer (HSD) (Source: Nikola Ždímalová, 2015)

3.4 Experimental procedure and instrumentation

Drying experiments started at 12:30 PM the first day and at 8:45 AM the second day. The drying procedure ended for both days at 6:00 PM. At the end of the first day, all samples were collected and placed to the room in closed plastic boxes and stored during the night. Within the drying process, weight loss (g) was measured every hour with digital weighing scale (Soehnle professional, Backnang, Germany) with a 0.1 g precision uncertainly. Ambient and drying temperature (°C), ambient and drying relative humidity (%) were measured by Minidataloggers Testo 174H (Testo Lenzkirch, Germany), which was installed outside and also inside the drying chamber. Air velocity was measured by Anemometer Testo 425 (Testo, Lenzkirch, Germany) with an accuracy ±0.03 $m \cdot s^{-1}$. Pyranometer CMP 6 with a solar integrator (KippZonen, Delft, the Netherlands) with daily accuracy ±5% was used to measure global solar radiation ($W.m^{-2}$). All values were measured every hour.

3.5 Moisture content and moisture ratio calculation

To calculate moisture content on dry basis was used equation (3) and to calculate moisture content wet basis was used equation (4) (Belessiotis and Delyannis, 2011). The mean values were used for further calculation:

$$MC_{db} = \frac{water(kg)}{drymeat(kg)} \quad (3)$$

$$MC_{wb} = \frac{water(kg)}{water(kg) + drymeat(kg)} \quad (4)$$

To evaluate the drying curves of fish samples, processed by all types of drying, the measured moisture content (MC) measured was transformed into the moisture ratio (MR) as describe in equation (5) and simplified in equation (6) (Rayaguru and Routray, 2012).

$$MR = \frac{M(t) - M_e}{M_i - M_e} \quad (5)$$

$$MR = \frac{M_t}{M_i} \quad (6)$$

Where: MR - moisture ratio

$M_{(t)}$ - moisture content at any time (% d.b.)

M_i - initial moisture content (% d.b.)

M_e - equilibrium moisture content (% d.b.)

t - time (min)

3.6 Sensory analysis

Two independents panels were organized. First panel of 24 panelists evaluated dried fish samples prepared in EO and the second panel of 29 panelist evaluated boiled fish samples. All panelist of sensory analysis were mainly students of CULS and RUA participating in the summer school. All panelist were trained. Each sample was designated by 4 numbers digit code (see Table 3). For evaluation was used the profile method and it has been used structure scale. Evaluated parameters were: appearance, aroma, taste, texture, overall acceptability, with used scale: 1-5 (1-excellent, 2-very good, 3-good, 4-satisfactory, 5-poor). The original sensory analysis form see in Anexx (Table 13 and Table 14). Both panels evaluated all five fish species (WC, CH, NT, PG, SB). For evaluating the boiled fish, firstly the samples were treated with 3.5 % of saline solution for one hour and then boiled in fresh water. All samples were evaluated after 30 minutes of boiling. Dried samples, which were evluated by first panel, had been also treated raw before drying with 3.5% of saline solution for one hour.

Table 4. Numbers of codes for sensory analysis

Fish samples	Walking catfih	Silver barb	Nile tilapia	Channa	Pangasius
Boiled and dried fish samples	8964	3417	3912	8123	2256

3.7 Questionnaires

The questionnaire which was used, contained thirteen questions. All question were focused on drying of selected fish species in Cambodia. Part of the questions was focused on preferences of Cambodian people related to dried fish. It also analyzed how much money they spend for dried or semi-dried fish species. All 30 respondents were from Cambodia, mainly students from RUA or participants of summer school. The questionnaire is attached in annexx Figure 32.

3.8 Statistical analysis

Data were analyzed with the Statistica software for analysis of variance of main effects. As a standard test was chosen One Way ANOVA test and Scheffe's test was used as a posthoc test.

4. Results and discussion

4.1 Drying conditions

The values of ambient temperature, ambient relative humidity (RH), and the global solar radiation ranged during two days of measurig between 27°C and 44.8°C, 39.1% and 85.3%, 89.8 W.m^{-2} and 147.4 W.m^{-2}, respectively, see Figure 12.

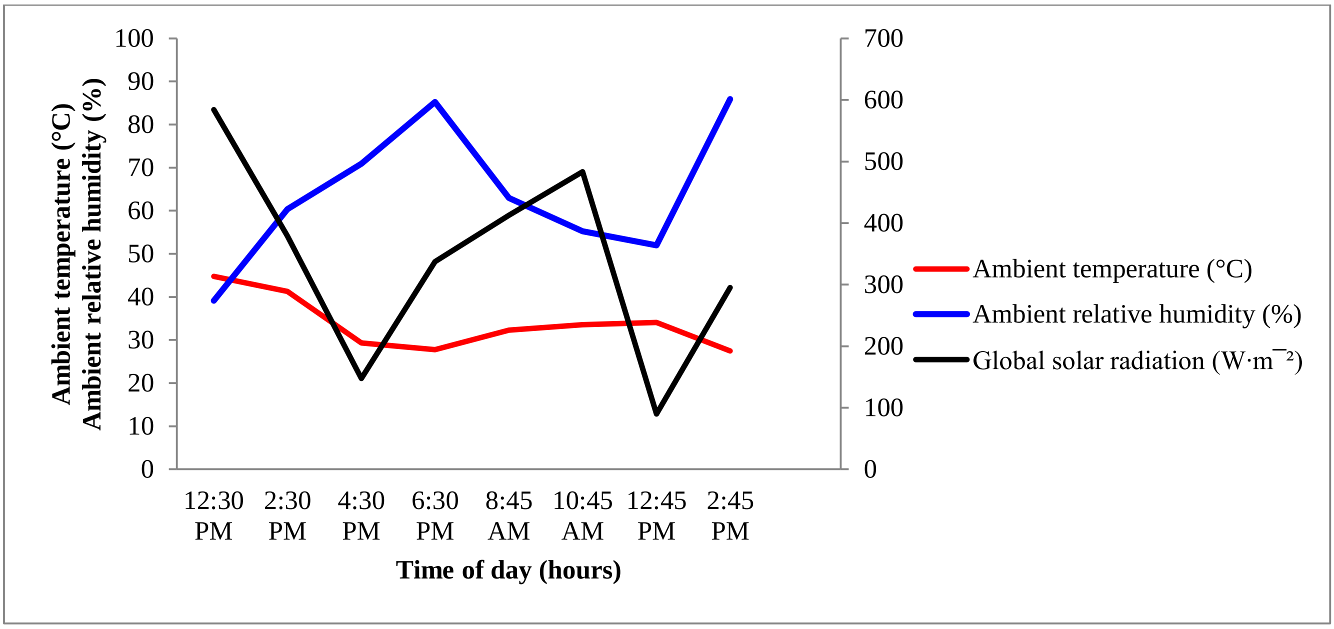


Figure 12. Air temperatures, air relative humidity and solar radiation during drying experiment

The next Figure 13 illustrates the changes between temperature and relative humidity inside the hybrid solar dryer in the same reporting time. Values of the temperature within the dryer ranged from 31.1°C and 49.6°C. The monitored relative humidity inside dryer ranged between extreme values of 27.6% and 62.3%.

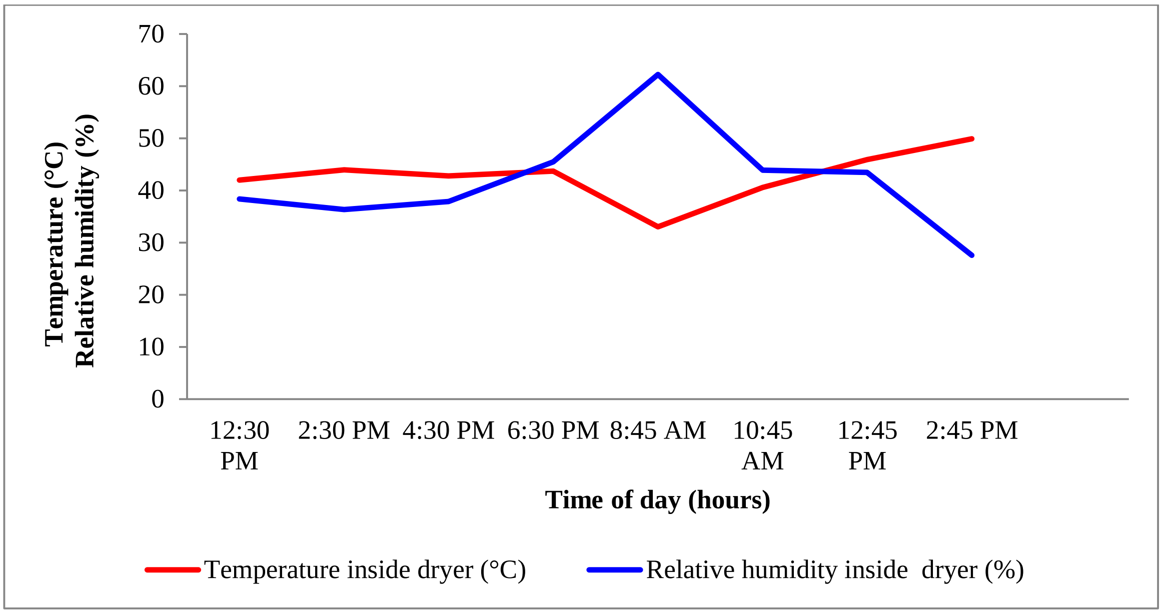


Figure 13. Temperature and relative humidity inside hybrid solar dryer during drying experiment.

In the greenhouse dryer (see Figure 14) were monitored the same parameters as in the HSD. Temperature was between 41.4°C and 76.2°C. The measured relative humidity were recorded between 8.7% and 33.12%.

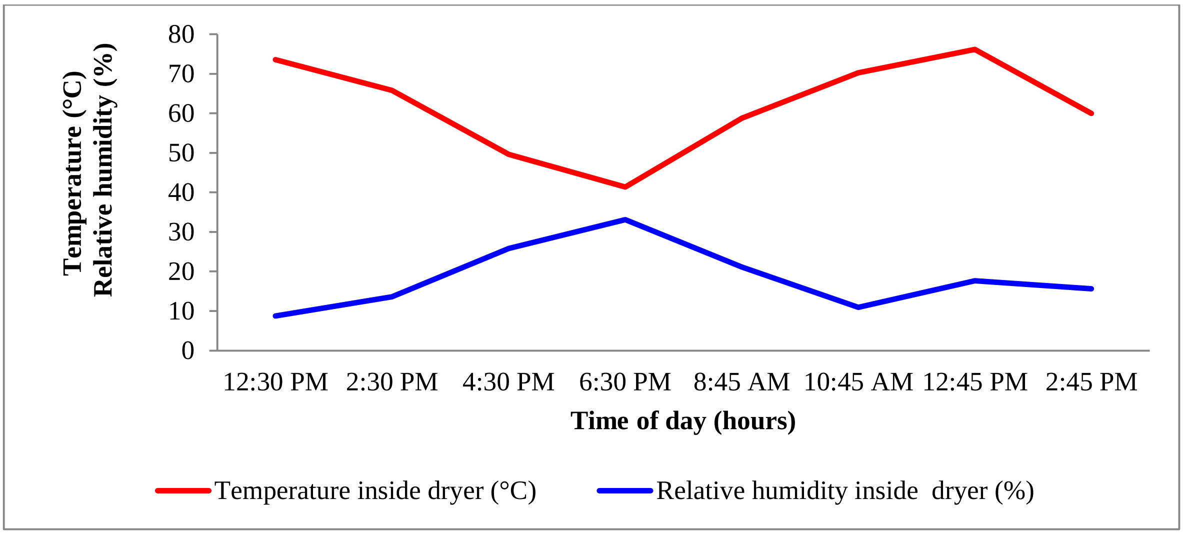


Figure 14. Temperature and relative humidity inside greenhouse during drying experiment.

From the curves which are presented in figures (12-14). It is evident that drying air temperature and drying air relative humidity have a contradictory run. It is clear that maximum drying temperature between 12:30 PM first day and 2:45 PM second day did not exceed a temperature 70°C which is regarded as a maximum temperature for drying of fish (Rahman, 2006).

4.2 Moisture content wet basis (MC_{wb})

The following table (see Table 4) presents the reduction of moisture content of different fish species in three dryers: hybrid solar dryer (HSD), greenhouse dryer (GH), eletric oven (EO). The values of final moisture contents were comparable in all types of dryers, but the lowest values of moisture content (wet basis) reached the samples dried in greenhouse dryer followed by hybrid samples dried in solar dyer followed by eletric oven. These values seems similar as the results of (Amer et al., 2009). This similarity of final moisture contents of samples dried in different dryers can be probably caused more by external influences (relative temperature, relative humidity and solar radiation) than by different type of dryer. Values of MC in the case of WC samples dried in GH agree with previously study by (Oparaku et.al., 2013).

Table 5. Moisture content wet basis (MC_{wb}) of fish species in different dryers

Dryer	Treat.	Fish samples	Initial MC_{wb}	Final MC_{wb}	STD
HSD					
	S	PG	0.832	0.197	0.336
	S	CH	0.800	0.195	0.331
	S	NT	0.765	0.172	0.325
	S	WC	0.808	0.194	0.343
	S	SB	0.741	0.171	0.403
GHD					
	S	PG	0.793	0.190	0.331
	S	CH	0.771	0.183	0.333
	S	NT	0.789	0.169	0.337
	S	WC	0.803	0.189	0.353
	S	SB	0.732	0.169	0.431
EO					
	S	PG	0.805	0.204	0.331
	S	CH	0.788	0.201	0.333
	S	NT	0.781	0.160	0.337
	S	WC	0.807	0.191	0.352
	S	SB	0.776	0.171	0.427
	UNS	PG	0.787	0.189	0.310
	UNS	CH	0.764	0.199	0.319
	UNS	NT	0.772	0.176	0.329
	UNS	WC	0.793	0.187	0.339
	UNS	SB	0.786	0.165	0.407

4.3 Influence of different fish species on drying kinetics

4.3.1 Influence of different fish species on drying kinetics in greenhouse dryer

It was observed that the only SB and PG showed a changes on drying speed. This was probably due to the lower initial moisture content, more over combined with lower content of fat in case of SB which possitively influencing drying speed as can be in Figure 15.

As it is evident from figure bellow (see Figure. 15) SB was dried the fastest. After 16 hours of drying the PG reached the highest values of MR (0.27). It proves, that PG in greenhouse is dried the slowest, what is cause by high content of fatty acid (Ho, B.T. and Paul, D.R 2009).

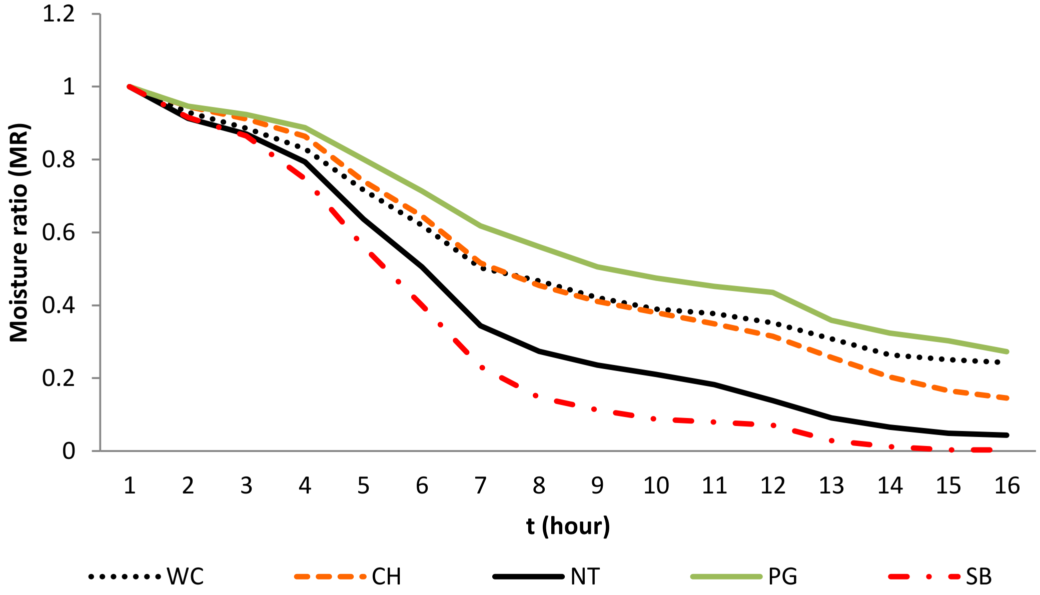


Figure 15. Experimental and predicted moisture ratio for greenhouse drying of WC, CH, NT,PG and SB (salted)

According to statistics analysis the drying speed differences highlighted on the graphs above are confirmed. Statistical significant difference ($p < 0.05$) was found in SB case confirming the results previously mentioned (see Table 5).

Table 6. One Way ANOVA Test + Scheff's Post –hoc, Greenhouse dryer

	WC	CH	NT	PG	SB
WC		0.999	0.286	0.897	**0.011**
CH	0.999		0.415	0.794	**0.023**
NT	0.286	0.415		**0.032**	0.738
PG	0.897	0.794	**0.032**		**0.000**
SB	**0.011**	**0.023**	0.738	**0.000**	

WCT: Walking Cat Fish; CH: Channa; NT: Tilapia; PG: Pangasius; SB: Silver Barp

4.3.2 Influence of different fish species on drying kinetics in hybrid solar dryer

Opposite to results obtained in GHD, in HSD (see Figure 16) no differences between the drying speed of different fish species samples can be observed. As can be see figure below. Moreover this is probably due to the lower drying temperature and higher relative humidity achieved in hybrid solar dryer.

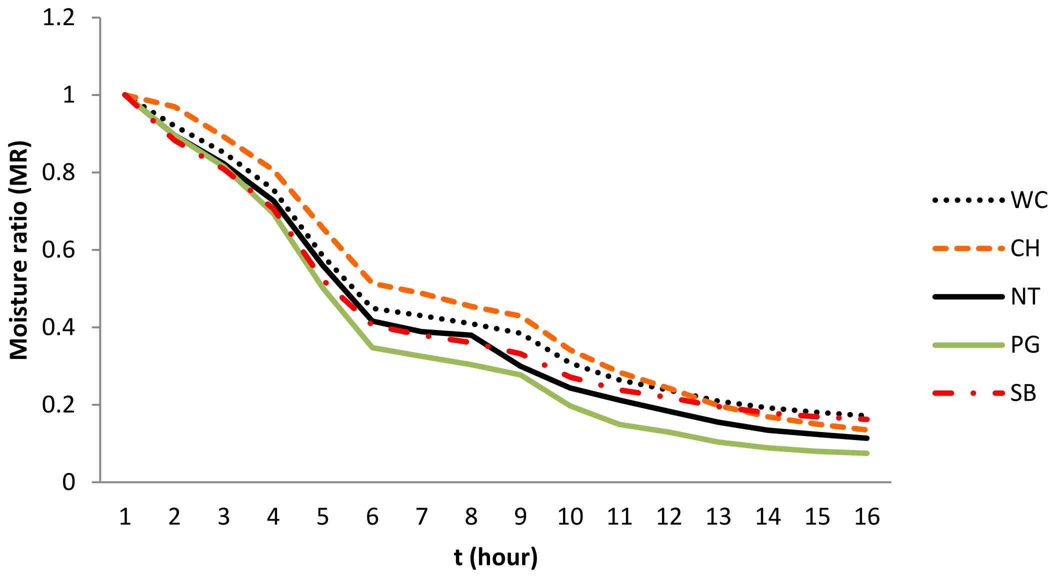


Figure 16. Experimental moisture ratio for hybrid solar dryer drying of WC, CH, NT,PG and SB (salted)

The same behavior was observed for solar dryer in the study of Hubacková at all (2014).

According to statistical analysis it is possible confirm, that there is no statistical significant difference among the different type of fishes dried in HSD (see Table 6).

Table 7. One Way ANOVA Test + Scheffe's- hoc, Hybrid Solar dryer

	WC	CH	NT	PG	SB
WC		0.997	0.969	0.718	0.990
CH	0.997		0.861	0.491	0.923
NT	0.969	0.861		0.973	1.000
PG	0.718	0.491	0.973		0.937
SB	0.990	0.923	1.000	0.937	

WCT: Walking Cat Fish; CH: Channa; NT: Tilapia; PG: Pangasius; SB: Silver Barp

4.3.3 Influence of different fish species on drying kinetics in eletric oven

In EO all type of fish species behaved the same, most probably because convection oven was used allowing both the air distribution and moisture evaporation to be equally distributed.

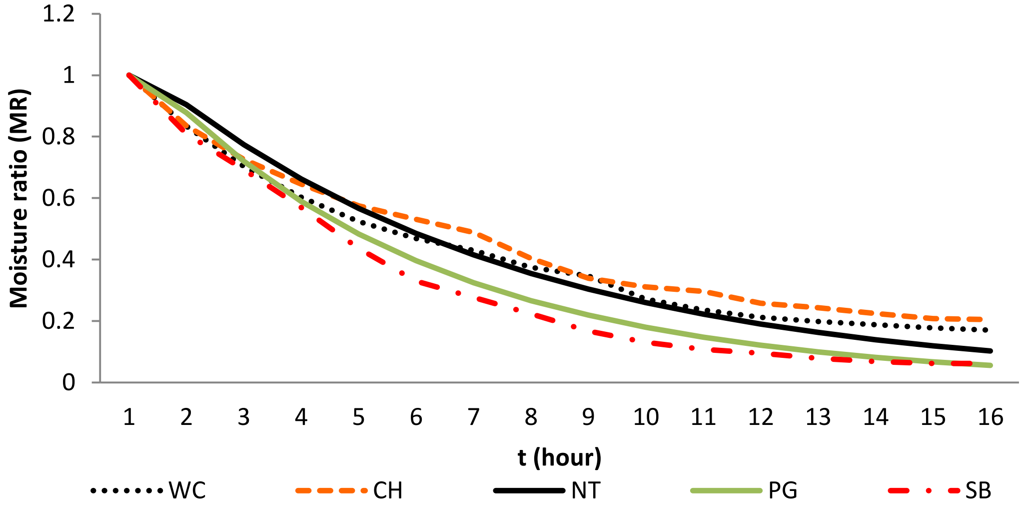


Figure 16. Experimental moisture ratio for electric oven drying of WC, CH, NT,PG and SB (salted)

Due to statistical analysis it is possible conclude, that there was no statiscally significant difference among the different type of fishes during drying in electric oven (see table 8).

Table 8. One Way ANova Test + Scheffe's Post -hoc Eletric oven

	WC	CH	NT	PG	SB
WC		0,901	0,938	0,997	0,999
CH	0,901		1,000	0,730	0,972
NT	0,938	1,000		0,795	0,987
PG	0,997	0,730	0,795		0,974
SB	0,999	0,972	0,987	0,974	

WCT: Walking Cat Fish; CH: Channa; NT: Tilapia; PG: Pangasius; SB: Silver Barp

4.4 Influence of different dryer on drying kinetics

4.4.1 Influence of different dryer on drying kinetics - Results of Walking catfish (WC)

HSD and EO reached the lowest MR values during the drying of WC. These values of HSD and EO were almost similar what disagree with our hypothesis, that EO should reach significantly lower MR values.

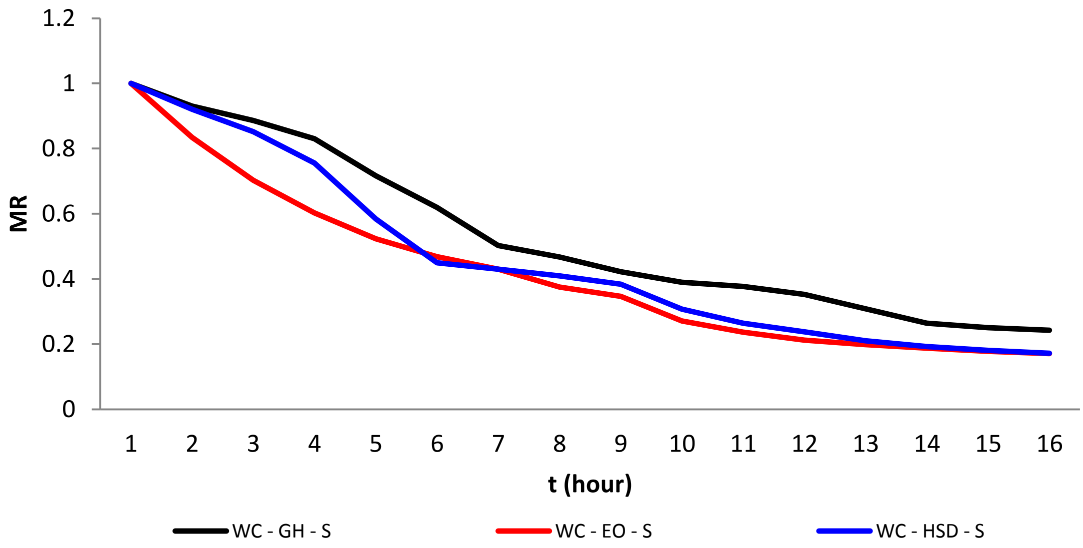


Figure 17 Experimental MR of WC in different dryers with different pretreatment

No statistical significant difference was found ($p>0.05$), nevertheless it can be confirmed that due to the effect of higher RH% and lower temperature the drying takes place faster on GH nonetheless this difference are not statistical significant different.

Table 9. One Way ANOVA Test + Scheffe's Post – hoc WC

	GH	EO	HD
GH		0.132	0.988
EO	0.132		0.178
HD	0.988	0.178	

4.4.2 Influence of different dryer on drying kinetics - results of Channa (CH)

In the case of drying CH, different methods of drying did not reflect big differences in the drying process (see Figure 22), which can be caused by firm texture of CH meat. Samples dried in HSD, reached the lowest MR values, which mean, that they were dried the fastest.

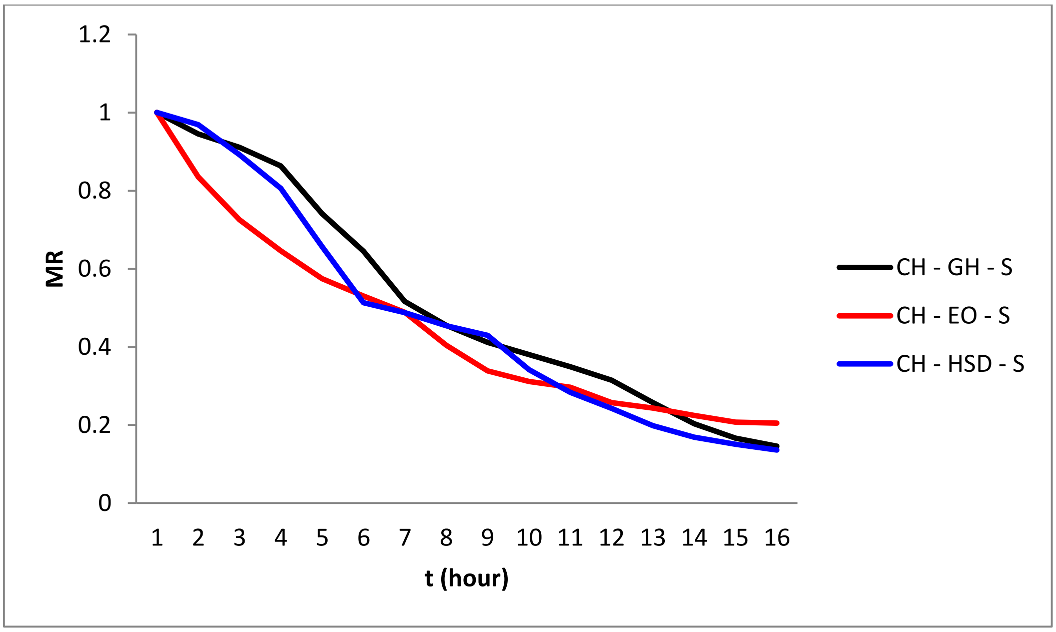


Figure 18 Experimental MR of CH in different dryers with different pretreatment

No statistical signifcant difference (p>0.05) was observedcan as direct result of different type of driers for CH type of fish.

Table 10 One Way ANOVA Test + Scheffe's Post-hoc CH

	GH	EO	HD
GH		0.096242	0.457186
EO	0.096242		0.318400
HD	0.457186	0.318400	

GH: Green House; EO: Electrical Oven; HD: Hybrid Dryer

4.4.3 Influence of different dryer on drying kinetics - results of Nile tilapia (NT)

Even though, samples of NT dried in GH showed the highest values of MR during first 6 hours, on the end of the drying, the same samples reached the lowest values of MR. In the case of drying in EO, the final values of MR, were not so low, as was expected before the drying. Conversely the final MR values of unsalted samples of NT dried in EO were the highest of all samples, which mean, that the samples were dried the slowest. (see Figure 23)

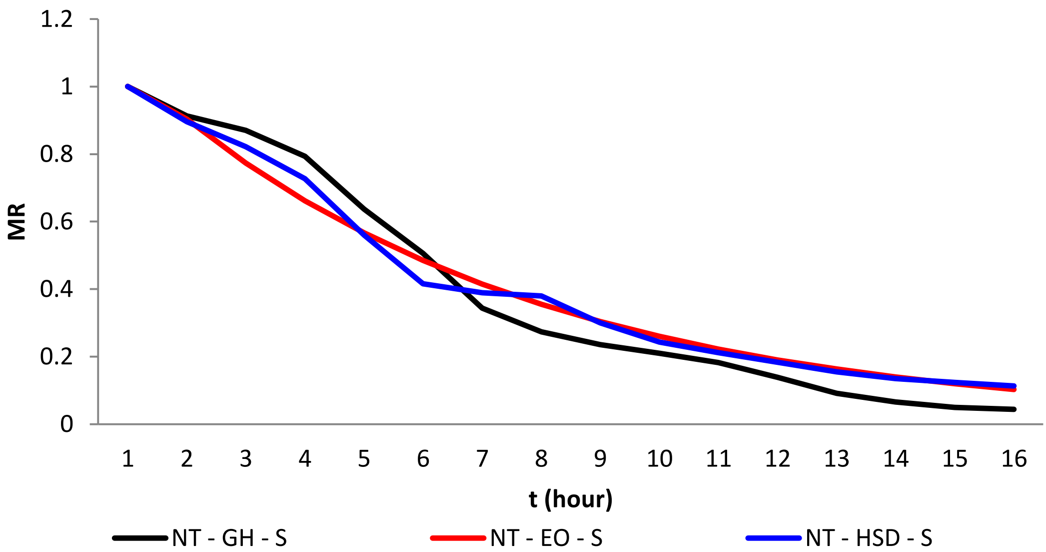


Figure 19 Experimental MR of NT in different dryers with different pretreatment

No statistical significant difference (p>0.05) can be observed as direct result of different type of driers for NT type of fish.

Table 11. One Way ANOVA Test + Scheffe's Post hoc NT

	GH	EO	HD
GH		0.816593	0.971638
EO	0.816593		0.924275
HD	0.971638	0.924275	

GH: Green House; EO: Electrical Oven; HD: Hybrid Dryer

4.4.4 Influence of different dryer on drying kinetics - results of Pangasius (PG)

In the case of PG, samples dried in GH showed difference in speed of drying compared to drying in HSD an EO (see Figure 24).

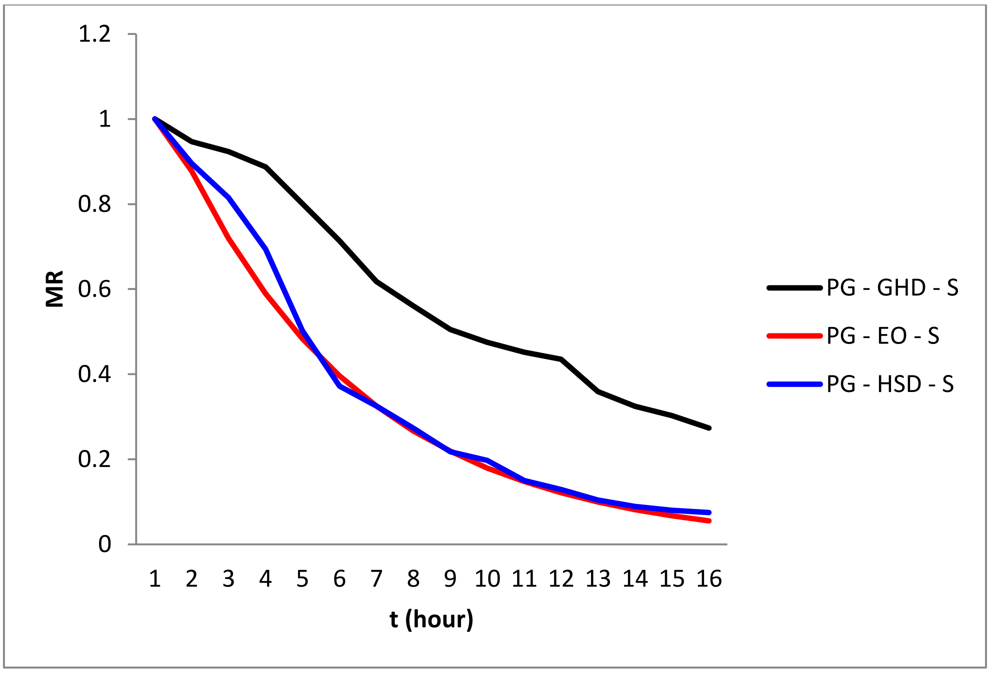


Figure 20 Experimental MR of PG in different dryers with different pretreatment

Same trend as that observed for WC is observed, having GH as the fastest one as adirect result of the combination of higher RH and lower temperature, in contrast those curves there is a statistical significant difference ($p<0.05$), between the curves of EO and HD compared to GH as it can be seen on the table below (see Table 12)

Table 12.One Way ANOVA Test + Scheffe's Post-hoc PG

	GH	EO	HD
GH		<u>0.000197</u>	<u>0.000002</u>
EO	<u>0.000197</u>		0.580845
HD	<u>0.000002</u>	0.580845	

GH: Green House; EO: Electrical Oven; HD: Hybrid Dryer

4.4.5 Influence of different dryer on drying kinetics - results of Silver barb (SB)

The samples of SB were dried the fastest in GH . The HSD reached much higher values of MR than GH or EO (see Figure 25).

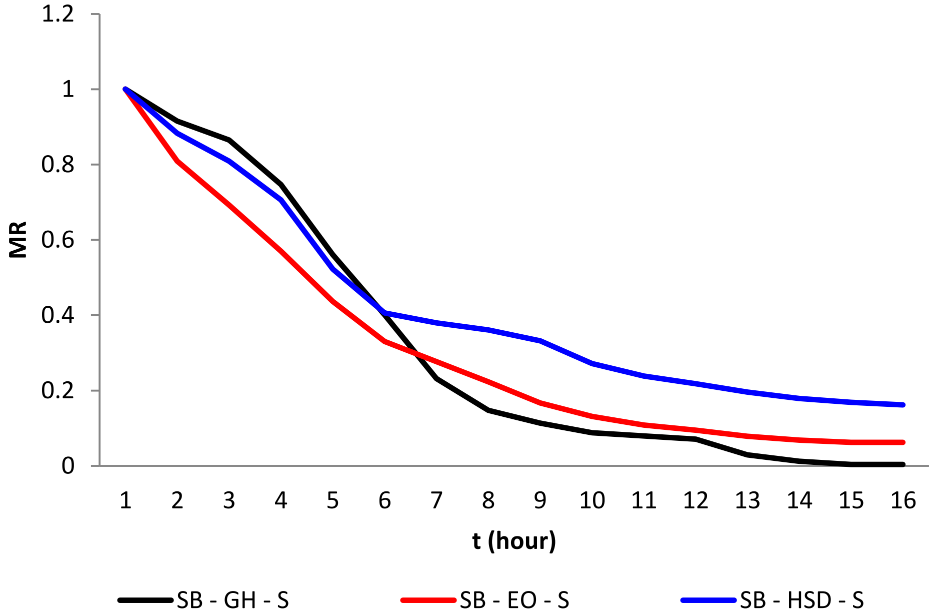


Figure 21 Experimental MR of SB in different dryers with different pretreatment

On the statistical analysis it is clearly seen, that the difference of drying behaviour highlighted on the results per dryer are confirmed. When comparing the drying speed on GH dryer versus EO and HD a statistically significant difference ($p<0.05$) can be observed (see Table 13) as a direct effect of the higher RH achieved in GH.

Table 13. One Way ANOVA Test + Scheffe's Post-hoc SB

	GH	EO	HD
GH		<u>0.008382</u>	<u>0.006378</u>
EO	<u>0.008382</u>		0.996011
HD	<u>0.006378</u>	0.996011	

GH: Green House; EO: Electrical Oven; HD: Hybrid Dryer

4.5 Influence of salting in drying kinetics

Five different fish species all in two variants were dried in EO. Each fish species was salted and unsalted (control sample). Comparison of salted versus unsalted fish samples using one way Anova Test showed statistical significant difference ($p<0.05$) between them. Similar results were observed by Segar et al (2009). (see Table 14).

Table 14. One Way Anova Test, statistical analysis of salted and unsalted in EO

	SALTED	UNSALTED
SALTED		**<u>0.000</u>**
UNSALTED	**<u>0.000</u>**	

4.6 Sensory analysis

4.6.1 Boiled fish

The results of sensory analysis of five boiled fish species (WC, CH,NL,PG, SB) are shown in Figure 26. The best score of all evaluated parameters obtained in case of WC, following by NT. These findings correspond to the results of similar studies where the best score was in case of Climbing perch, following by WC and NT (Hubáčková et all. 2014). Conversely, the worst score were obtained in case of PG and SB.

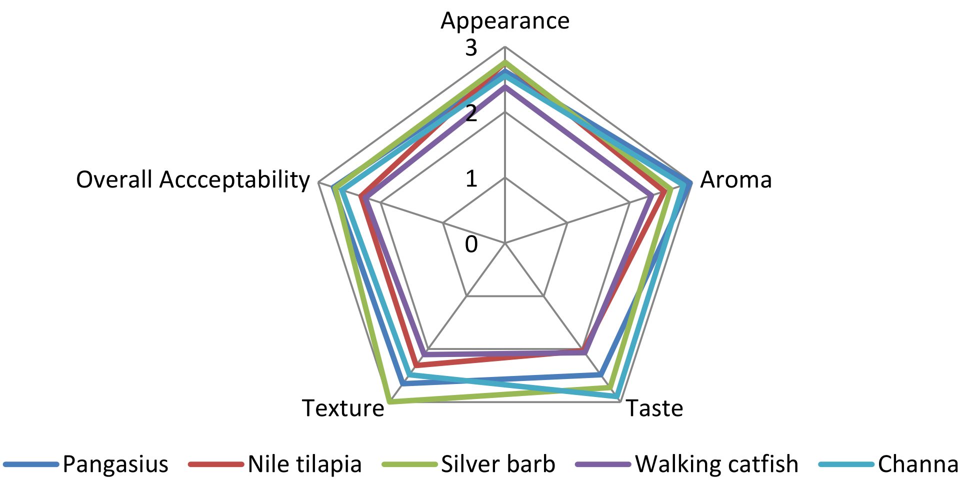


Figure 22. Spider diagram of sensory analysis of boiled samples of fish

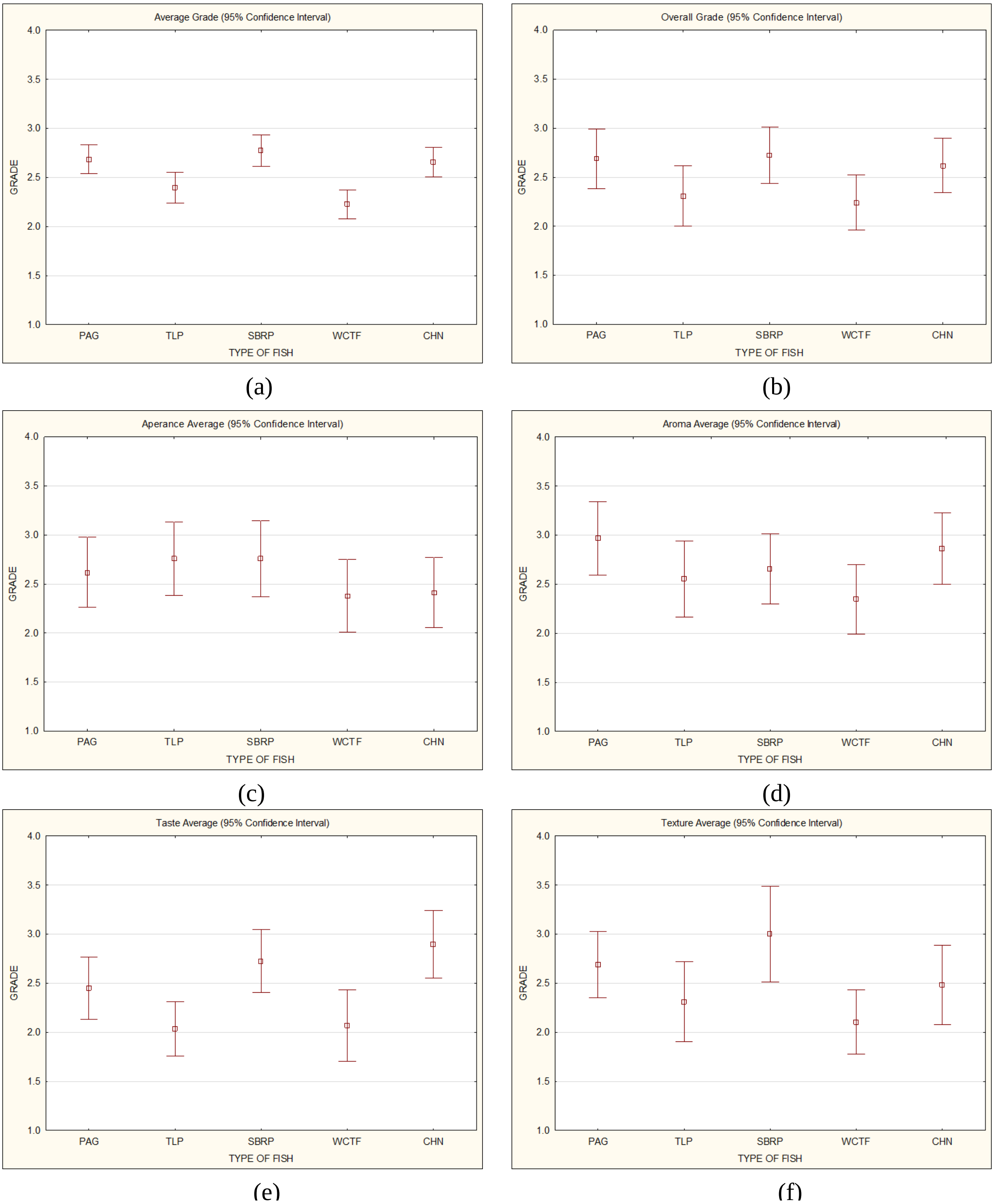


Fig. 27 Sensory analysis of boiled fishes - statistical results.

(a) Average of grades; (b) Overall Aceptance; (c) Aperance; (d) Arome; (e) Taste; (f) Texture.
PAG: Pangasius; TLP: Tilapia; SBRP: Silver Barp; WCTF: Walking Cat Fish; CHN: Channa.

It can be observed that the statistical analysis shows results in acccordance to those already presented in spider graph, furthermore, we can see, that WC is the best performer on all the categories, ($p<0.05$) when compared to the other fish species.

Table 15. Statistical analysis overall average sensorial analysis boiled samples

	PG	NT	SB	WC	CH
PAG		0.136037	0.954578	**0.001802**	0.999502
TLP	0.136037		0.682176	**0.017668**	0.220004
SBRP	0.954578	0.682176		**0.000065**	0.886094
WCTF	**0.001802**	**0.017668**	**0.000065**		**0.004378**
CHN	0.999502	0.220004	0.886094	**0.004378**	

PG: Pangasius; NT: Nila Tilapia; SB: Silver Barp; WC: Walking Cat Fish; CH: Channa

4.6.2 Dried fish

Results of sensory analysis evaluating five dried fish species are presented in Figure 28. The best score in almost all categories obtained SB, followed by WC. The best performer SB was the best in overall average, but also in overall acceptability, aroma, taste and appearance, only in case of texture the best score had CH. However, the worst scores were observed in case of PG ($p<0.05$), which reached the same results as in the case of boiled samples. The second worst scores were obtained in case of dried samples of WC, which oppositely reached the best score in degustation panel of boiled fish samples.

Moreover, despite the better performance from SB, it was also found that besides the statistical significant difference with PG there is other significant difference with the rest of type of fishes.

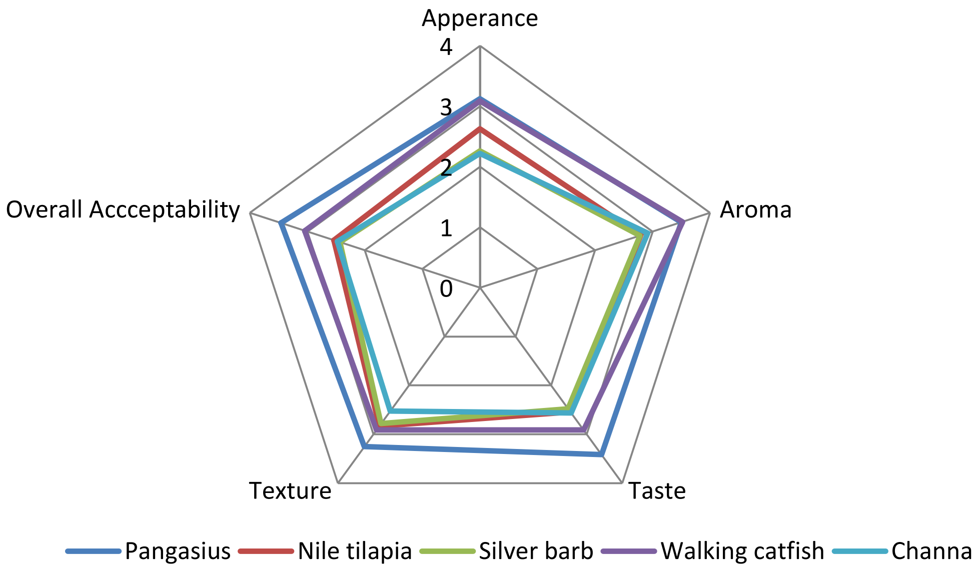
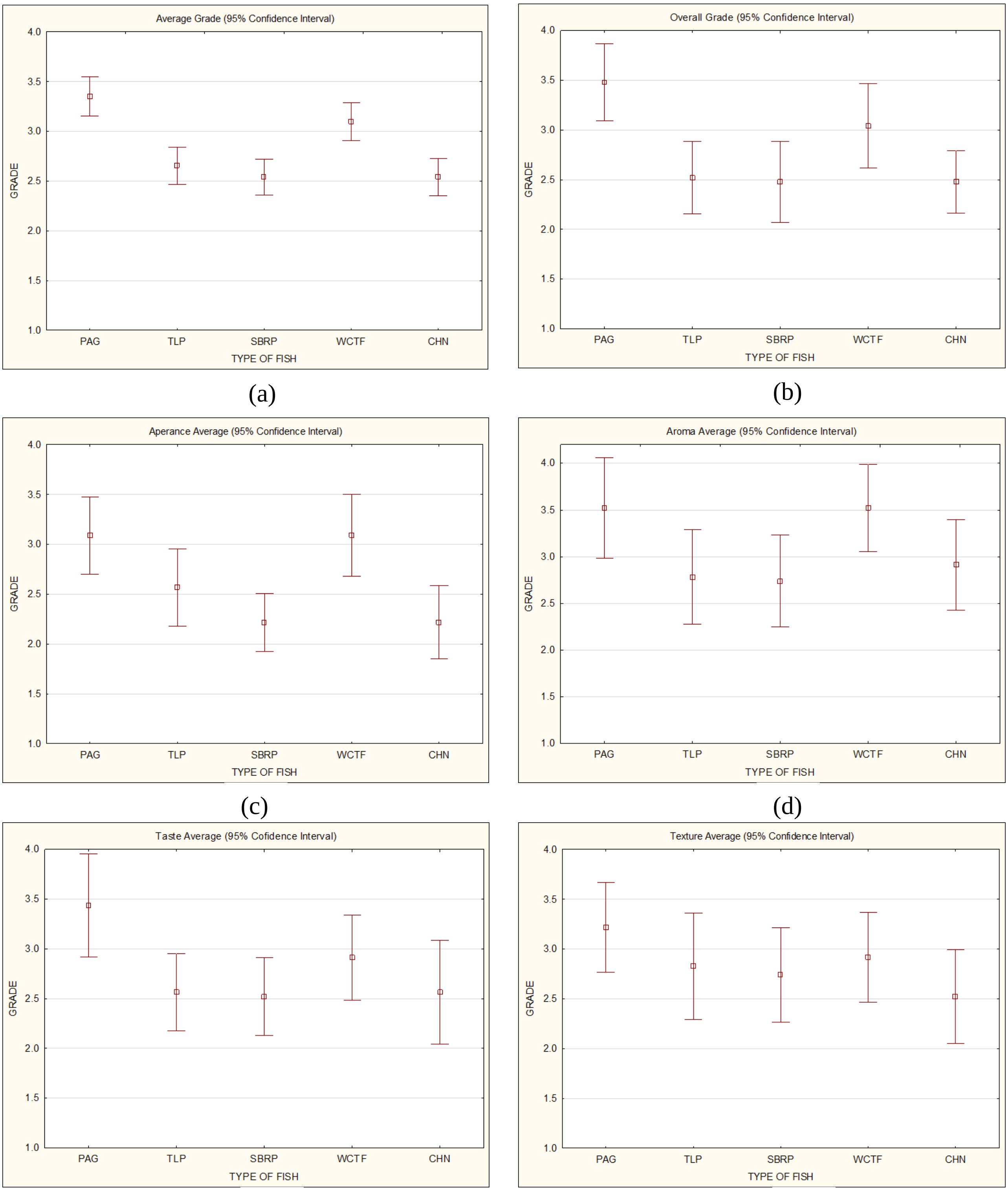


Figure 28. Spider diagram of sensory analysis of dried samples of fish



(a) (b) (c) (d) (e) (f)

Fig. 28 Salted sensory analysis statistical results.

(a) Average of grades; (b) Overall Aceptance; (c) Aperance; (d) Arome; (e) Taste; (f) Texture.
PAG: Pangasius; TLP: Tilapia; SBRP: Silver Barp; WCTF: Walking Cat Fish; CHN: Channa.

Table 16. Statistical analysis overall average of dried sensory analysis.

	PG	NT	SB	WC	CH
PG		**0.000011**	**0.015611**	**0.001739**	**0.001254**
NT	**0.000011**		0.495278	0.844060	0.877929
SB	**0.015611**	0.495278		0.979731	0.967878
WC	**0.001739**	0.844060	0.979731		0.999993
CH	**0.001254**	0.877929	0.967878	0.999993	

PG: Pangasius; NT: Nila Tilapia; SB: Silver Barp; WC: Walking Cat Fish; CH: Channa

4.7 Questionnarie

All respondents answered they consume dried fishes in their families. Almost all of them (28 respondents) buy all fishes in the market and only two respondents catch all fishes by them own. As it is shown in Figure 27 the most consumed fish species was Channa and the second most preferred fish was Pangasius, which is in agreement with the results reported by Hortle et al., 2004. 67 % of respondents answered, that they dry fishes by themselves and the rest do not. As we assumed only 3 % of respondents use the dryer but 87 % of them dry fishes under the sun, the rest 10% don’t dry the fish.

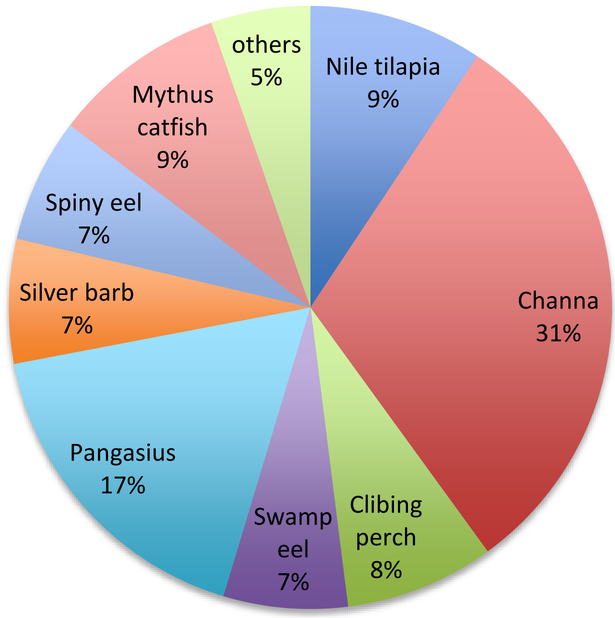


Figure 23. Preferred fish species to be consumed

In the questionnaire was a question asking about the spices used for flavouring. The following Figure 28 shows, that the most common spices are salt and sugar.

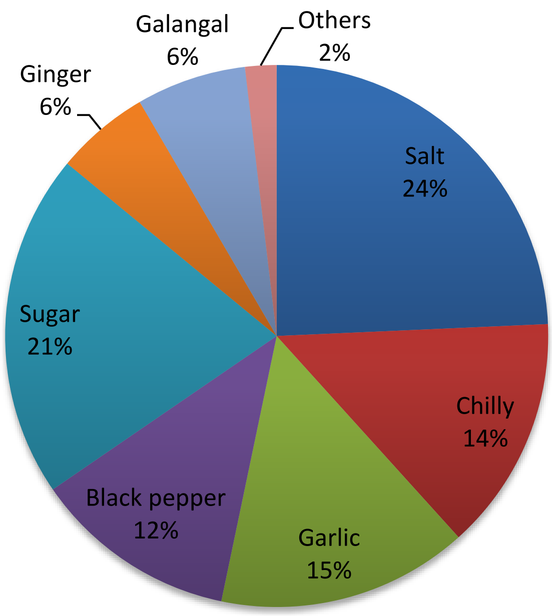


Figure 24. Preferred spices used for flavouring of fishes

The results of the questionnaire showed the respondents mostly spend only 0 – 5 USD a month in one household for dried fishes. On the other hand they spend much more money (12-17 USD) for fresh fishes, which they then dry by themselves.

5. Conclusion

Five most typical Cambodian fish species, namely Nile Tilapia (*Oreochromis niloticus*), Channa (*Ophicephalus sriatus*), Silver Barb (*Puntus gonionotus*), Walking catfish (*Clarias batrachus*) and Pangasius (*Pangasius hypophtalmus*) were selected for solar drying experiments in hybrid solar dryer (HSD), greenhouse dryer (GD) and electric oven (EO). Ambient temperature, ambient relative humidity and solar radiation ranged from 27.0°C to 44.8 °C, 39.1% to 85.3% and 89.8 to 147.4 W. m^{-2}, respectively

- With the exception of Silver barb dried in GD there were no statistically significant differences between drying in different types of dryers, as well as no statistical differences between drying behavior of all five fish species with respect to drying technology.

- It is possible to conclude that drying behavior of salted fish samples was statistically different ($p<0.05$) in comparison with drying behavior of fish samples without salt treatment. More over, this is due to the absorption effect over the moisture content , thus helping to the overall evaporation ratio of the moisture of the samples

- The most accepted fish according to the results from the sensory analysis is the Walking catfish good taste and texture, which is mostly due to its sweet water origin. Moreover this fish species is low cost and is high available throughout South Asia

- According to the questionnaire, the most consumed fish is Channa followed by Pangasius and from these results it was also confimered, that 67 % of all respondents dry fish by themselves and 87 % of all respondents use the open sun drying method instead of using the solar dryer.

References

Ahmed M., Tana T. S., Thuok N. 1996. Sustaining the gift of the Mekong: the future of the freshwater capture fisheries of Cambodia. Watershed 1 (3): March-June 1996.

Bailey R. 1994. Guide to the fishes of the River Nile in the Republic of the Sudan. Journal of Natural History 28: 937-970.

Bansok ROS, Phirun NANG, Chhun CHHIM. 2011. Agricultural development and climate change: The case of Cambodia. CDRI working paper series No. 65. ISBN-13: 978-99950-52-60-7

Bartley DM. 2005. International Mechanisms for the Control & Responsible Use of Alien Species in Aquatic Ecosystems: Report of an Ad Hoc Expert Consultation,

27-30 August 2003, Xishuangbanna, People's Republic of China. Rome: Food & Agriculture Org. 195p.

Belessiotis,V., Delyannis, E., 2011. Solar drying. Solar Energy 85, 1665-1691.

Beran E., Borin U. 2012. The iportance of the fish resourses in the Mekong River and examples of best practices. P. 136-141.

CHEN XD. 2008**.**Drying Technologies in Food Processing. Singapore: John Wiley & Sons, 352. ISBN 978-1-4051-5763-6.

Ciurzyńska A, Lenart A. 2011. Freeze drying: Application in Food Processing and Biotechnology. Pol. J. Food Nutr. Sci. 61: 171-174.

Courtenay WR, Williams JD. 2004. Snakeheads (*Pisces, Channidae*) – A Biological Synopsis and Risk Assessment. Title II. (U.S. Geological Survay circular; 1251. ISBN. 0-607-93720.

De Silva SS. 2004. Tilapias as alien aquatics in Asia & the Pacific: a review. Rome: Food & Agriculture Org. 65p.

Dicklich S, Milak A. 2010. Justice, human rights, and reconciliation in post-conflict Cambodia. Human Rights Review, 11: 515-530.

ECCA. 2005 (European Coil Coating Association). Thermodynamic behavior of moist air – Physical characteristics of moist air. Available at:http://www.eccacoil.com/main%2Dend%2Duses/buildings/document.asp?Ref=25 &RefTop=34

FAO. 2011. Fisheries & Aquaculture Country Profiles. Available at http://www.fao.org/fishery/facp/KHM/en: Accessed 2013-10-28.

FAO. 2016. Not dated [online]. Available at http://www.fao.org/fishery/species/2175/en

FELLOWS JP.2000. Food processing technology, Principles and practice, 2 edition. Cambridge:575 p. ISBN 1-85573-533.

Gindelberger B. 1981. Why Sinarapan almost disappeared from Lake Buhi. Fishery management in Camarines Sur, Philippines: 3-5.

Hall CW. 1979.Dictionary of drying. New York: Marcel Dekker, Inc. 349 p. ISBN 0-8247-6652-0.

Hill MT, Hill SA. 1994. Fisheries ecology and hydropower in the lower Mekong River: an evaluation of run-of-the-river projects. Mekong Secretariat, Bangkok, Thailand. 106 p.

Hubackova A, Kucerova I, Chrun R, Chaloupkova P, Banout J. 2014. Development of solar drying model for selected Cambodian fish species. The scientific world jurnal. Article ID 439431. 10 p.

Hortle KG. 2007. Consumption & the yield of fish & other aquatic animals from the Lower Mekong Basin. MRC technical paper 16: 1-88.

Jangham AS, Law CHL, Mujumdar AS. 2011. Drying of foods, vegetables and fruits (volume 2). ISBN. 978-981-08-7985-3.

Kottelat M. 1989. Zoogeography of the Fishes from Indochinese Inl& Waters with an Annotated Check-list. Universiteit van Amsterdam: Zoölogisch Museum. 56p.

Kottelat M. 1998. Fishes of the Nam Theun & Xe Bangfai basins, Laos, with diagnoses of twenty-two new species (Teleostei: Cyprinidae, Balitoridae, Cobitidae, Coiidae & Odontobutidae). Ichthyological Exploration of Freshwaters 9: 1-128.

Kudra T, Mujumdar AS. 2009. Advanced Drying Technologies. US: CRC Press, 483p.

Kyzlink V. 1998. Teoretické základy konzervace potravin. Praha: SNTL - Nakladatelství technické literatury Alfa, 511 s.

Lagler KF. 1976. Fisheries & integrated Mekong River basin development: terminal report of the Mekong Basinwide Fishery Studies. Michigan: University of Michigan, School of Natural Resources. 49p.

Mujumdar AS. 2007. Handbook of industrial drying. US: CRC Press, 710p.

Osmose. 2013. The waterway between Battambang & Siam Reap - Introduction to the Southeast Asia´s largest lake. 31p.

Philippart JC, Ruwet JC. 1982. Ecology & distribution of tilapias: In R.S.V. Pullin & R.H. Lowe-McConnell (eds.) The biology & culture of tilapias. ICLARM 7: 15-60.

Pillay TVR, Kutty MN. 2005. Aquaculture: principles & practices: Blackwell publishing. 624p.

Prvulovic S, Tolmac D. 2007. Convection drying in the food industry. International Commission of Agricultural Engineering: 1682-1130.

Rahman MS, Mujumdar AS. 2006. Drying of fish and seafood, in Handbook of Industrial Drying, Ed., pp. 547–562.

Rahman MS. 1999. Handbook of Food Preservation. New York: CRC Press, 1088p.

Roberts TR. 1993. Artisanal fisheries and fish ecology below the great waterfalls of the Mekong River in southern Laos. Nat. Hist. Bull. Siam Soc. 41:31-62.

Simpson WT. 1987**.** Vacuum drying northern red oak. Forest products journal 37: 35-38.

Sokheng C, Chhea CK, Viravong S, Bouakhamvongsa K, Suntornratana U, Yoorong N, Tung NT, Bao TQ, Poulsen AF, Jørgensen JV. 1999. Fish migrations and spawning habits in the Mekong mainstream: a survey using local knowledge (basin-wide).

Song S, Sopha L, Try I, Sotharith H. 2005. The Unsustainable Exploitation of Inland Fisheries Resources in Cambodia.

Sopian K., Sayigh A., thman my. 2006. Solar Assisted Drying Systems: Solar assisted heat pump drying. Publications of the Islamic Educational, 128-146.

Stickney RR. 2000. Encyclopedia of aquaculture. Vancouver: John Wiley & Sons. 1080p.

UNDP, United Nation Development Program. 2014. a) HDI available at http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/KHM.pdf and b) International human development indicator of Cambodia available at http://hdr.undp.org/en/countries/profiles/KHM

Valbo-Jørgensen J, Coates D, Hortle K. 2009. Fish Diversity in the Mekong River Basin. Campbell IC editors. The Mekong. San Diego: Academic Press, p161-196.

Vega-Gálvez A, Ah-Hen K, Chacana M, Vergara J. 2011. Effect of temperature and air velocity on drying kinetics, antioxidant capacity, total phenolic content, color, texture and microstructure of apple (var. Granny Smith) slices. Food Chemistry 132: 51–59.

WB, The World Bank. (2012). On the World Wide Web:http://wwwwds.worldbank.org

(2014). Cambodia overview, available at http://www.worldbank.org/en/country/cambodia

WEISS W, BUCHINGER J. 2003Solar drying: establishment of a production, sales and consulting infrastructure for solar thermal plants in Zimbabwe. [online]. 110 [2012-03-17]. Published on URL: http://www.aee-intec.at/0uploads/dateien553.pdf

Welcomme RL, Vidthayanon C. 2003. The impacts of introductions & stocking of exotic species in the Mekong Basin & policies for their control. Cambodia: Mekong River Commission Cambodia. 35p.

Welcomme, R.L., 1988. International introductions of inland aquatic species. FAO Fish. Tech. Pap. 294. 318 p.

ANNEX A

1) Do you buy or catch the fishes? (please specify which species?)

តើត្រី ដែលអ្នកបរិភោគ បានមកពីការនេសាទ ឬទិញពីទីផ្សារ?

☐Buy all/ទិញ ☐Catch all/នេសាទ ☐Other______ផ្សេងៗ

2) Do you consume dried fishes in your family?

តើគ្រួសាររបស់អ្នកបរិភោគត្រីហាល/សំងួត ដែរឬទេ?

☐Yes បាទ/ចាស ☐No ទេ

3) Which type of dried fishes you prefer to consume?

តើត្រីហាលឬសំងួត ប្រភេទណា ដែលអ្នកចូលចិត្តបរិភោគ?

☐Channa ត្រីផ្ទោ ☐Pangasius ត្រីប្រា ☐Walking catfish ត្រីអណ្តែង

☐Nile Tilapia ត្រីទីឡាព្យាឈ្នូត ☐Silver carp ត្រីកាបស

☐Climbing perch ត្រីក្រាញ់ស្រែ ☐Spiny eelត្រីខ្ជឹង ☐Mystus Catfish ត្រីកញ្ចុះ

☐Swamp eel ត្រីអន្ទង់ ☐Silver barb ត្រីឆ្ពិន ☐Others______ត្រីផ្សេងៗ

4) How do you prefer to consume dried fishes?

តើអ្នកចូលចិត្តយកត្រីហាលឬសំងួត ទៅធ្វើម្ហូបប្រភេទអ្វីខ្លះ?

☐Baking ដុត ☐Cooking ចំអិន ☐Boiling ស្ងោរ ☐Frying ចៀន

☐Grill អាំង ☐Others ផ្សេងៗ

5) Do you dry the fishes by yourself?

តើអ្នកហាល/សំងួតត្រី ដោយខ្លួនឯង?

☐Yes បាទ/ចាស ☐No ទេ ☐Other ផ្សេងៗ

6) Do you buy dried or semi-dried fishes?

តើអ្នកទិញត្រីហាលស្ងួត ឬត្រីហាលមិនសូវស្ងួត?

☐Dried ហាលស្ងួត ☐Semi-dried ហាលមិនសូវស្ងួត ☐Both ទាំងពីរ

7) How often do you buy them?

តើអ្នកទិញត្រីហាល/សំងួតប៉ុន្មានដងក្នុងមួយសប្តាហ៍?

☐every day រាល់ថ្ងៃ ☐3 times per week ៣ដងក្នុងមួយសប្តាហ៍

☐2 times per week ២ដងក្នុងមួយសប្តាហ៍ ☐ones per week ១ដងក្នុងមួយសប្តាហ៍ ☐other____ ផ្សេងៗ

8) Which months do you dry fishes?

តើខែណាខ្លះ ដែលអ្នកហាល/សំងួតត្រី?

☐January មករា ☐February កុម្ភៈ ☐March មិនា ☐April មេសា

☐Mayឧសភា ☐June មិថុនា ☐July កក្កដា ☐August សីហា

☐September កញ្ញា ☐October តុលា ☐November វិច្ឆិកា ☐December ធ្នូ

9) Which method of drying do you use?

តើអ្នកហាល/សំងួតត្រីដោយវិធីសាស្រ្តណាខ្លះ?

☐Under the sun ហាល/សំងួតដោយពន្លឺថ្ងៃ ☐In dryer ប្រើប្រាស់ម៉ាស៊ីនសំងួត

☐Others_____ ផ្សេងៗ

10) Which spices do you use for flavouring ?

តើគ្រឿងផ្សំ ដែលអ្នកប្រើប្រាស់សម្រាប់ប្រឡាក់ត្រីមានអ្វីខ្លះ?

☐Salt អំបិល ☐chilly ម្ទេស ☐garlic ខ្ទឹមស ☐black pepper ម្រេច

☐sugar ស្ករស ☐ginger ខ្ញី ☐galangal រំដេង ☐Others______ផ្សេងៗ

11) How many persons live in your household?

តើគ្រួសាររបស់មានសមាជិកប៉ុន្មាននាក់?

12) How many dollars do you spend for dried and semi-dried fishes in your household per one month?

តើអ្នកចំនាយប្រាក់ ទៅលើការទិញត្រីហាលស្ងួត និងត្រីហាលមិនស្ងួត សម្រាប់បរិភោគក្នុងគ្រួសារប៉ុន្មានដុល្លា ក្នុងមួយខែ?

☐0-5 USD ០ទៅ៥ដុល្លា ☐6-11 USD ៦ទៅ១១ ដុល្លា

☐12 – 17 USD ១២ទៅ១៧ដុល្លា ☐18-23 USD ១៨ទៅ២៣ ដុល្លា

☐24 and more ច្រើនជាង២៤ដុល្លា

13) How many dollars do you spend in your household for fresh fishes, which you then dry by yourself?

តើអ្នកចំនាយប្រាក់ ទៅលើការទិញត្រីស្រស់ សម្រាប់បរិភោគក្នុងគ្រួសារប៉ុន្មានដុល្លា ក្នុងមួយខែ?

☐0-5 USD ០ទៅ៥ដុល្លា ☐6-11 USD ៦ទៅ១១ ដុល្លា

☐12 – 17 USD ១២ទៅ១៧ដុល្លា ☐18-23 USD ១៨ទៅ២៣ ដុល្លា

☐24 and more ច្រើនជាង២៤ដុល្លា

Figure 25. Questionnarie - Household survay

Table 17. Sensory analysis form

Sensory Evaluation Form						
Consumer test of BOILED FISH						
Sex…………………..……………………………Age………………………………….						
Please evaluate each of the five (5) coded samples.						
Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your preference 1 - 5 in the column against each attribute.						

Table 18. Sensory analysis form 2.

Sensory Evaluation Form						
Consumer test of DRIED FISH						
Sex…………………..……………………………Age………………………………….						
Please evaluate each of the five (5) coded samples.						
Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your preference 1 - 5 in the column against each attribute.						

Annex B

Figure 26. Silver barb (source, Miloslav Petrtýl, 2015)

Figure 27. Walking catfish (source, Miloslav Petrtýl, 2015)

Figure 28: Pangasius (source, Miloslav Petrtýl, 2015)

Figure 29. Nile tilapia (source, Miloslav Petrtýl, 2015)

Figure 30. Channa (source, Miloslav Petrtýl, 2015)