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MASTER THESIS

Videoanalysis of the feeding behaviour of Nile Tilapia (*Oreochromis niloticus*) for usage in the small-scale cage aquaculture in Kenya, East Africa

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Abstract

Aquaculture provides a seasonally independent, stable, predictable and secure production of fish under controlled conditions [BOROWY, 2009]. Within the framework of the EC-funded research project BOMOSA (www.bomosa.org) the creation of sustainable structures for the rearing of indigenous fish in East Africa is attempted. The proceeds from the sale of fish is therefore a promising tool for poverty reduction. Nile Tilapia (*Oreochromis niloticus Linnaeus*) is characterized by its good compatibility for a wide range of environmental influences as an ideal fish for aquaculture in developing countries. As an omnivore, feeding costs can be kept lower than in carnivores. Therefore it is an important source of high quality protein for human nutrition at low cost. The used fish feed should be simply and inexpensively produced of local ingredients, it should not constitute competition for human consumption or for the needs of the livestock, and furthermore contain the necessary nutrients for the fish.

The focus of this work is on investigating the acceptance of different feeds by tilapia under application of video analysis. It was also observed whether the food is suitable for the cage feeding. If it sinks too quickly, the use for the " cage-culture", where the fish are kept in cages, is limited.
From previous research ([ASSMANN, 2009]) it is known that the acceptance of the fish is good on spent grain (by-product from the brewery) and moderate on leaves of *Tithonia diversifolia* and *Ipomoea batatas*. A feed analysis ([GUTMANN, prep]) has shown that the individual components have good protein content.
For feed production leaves of Mexican sunflower (*Tithonia diversifolia*), Sweet potato (*Ipomoea batatas*) and Cassava (*Manihot esculenta*) were collected, dried and crushed. Thereafter they were each mixed with spent grain in different proportions and pelletized with the addition of a binder (gelatine or agartine). A total of 34 mixtures was produced in this way of which 13 were analyzed with video recording for proofing the acceptance.
In two tanks five fish were stocked with a weight of 60-80g and were fed three times a day. With a video camera installed in front of the glass panes, the feedings were filmed in sequences of eight minutes and afterwards analyzed. The obtained data were used as the basis for statistical analysis and interpretation of the feeding behavior. As reference a commonly used local feed was used which is adopted by the fish very well.

The results pointed out that the acceptability of the fish to a particular feed texture is increasing with an increasing proportion of spent grain. Mixtures with leaves of the Mexican sunflower are only bad accepted. Very often the behavior pattern of food intake, mastication and subsequent spitting out of certain particles was detected and statistically proved. It could not be determined whether these were spent grains or plant residues.
It was further observed that the diet is only partially applicable on cage culture system because of its too rapid sinking. Further tests should be conducted whether there are ways to keep the pellets on the ground of the networks, for example by using a tile.

Kurzfassung

Die Aquakultur bietet eine saisonal unabhängige, stabile, planbare und gesicherte Produktion von Fisch unter kontrollierten Bedingungen [BOROWY, 2009]. Im Rahmen des EU-finanzierten BOMOSA Forschungsprojektes (www.bomosa.org) wird in Ostafrika versucht, nachhaltige Strukturen für die Aufzucht heimischer Fische zu schaffen. Der Ertrag aus den verkauften Fischen ist somit auch ein viel versprechendes Instrument zur Armutsbekämpfung. Der Nil Tilapia (*Oreochromis niloticus Linnaeus*) zeichnet sich durch seine gute Verträglichkeit für ein weites Spektrum an Umwelteinflüssen als idealer Fisch für die Aquakultur in Entwicklungsländern aus. Da er ein Allesfresser ist, können die Futterkosten niedriger gehalten werden als bei Fleischfressern. Damit stellt er eine wichtige Quelle für hochwertiges Protein für die menschliche Ernährung bei gleichzeitig geringen Kosten dar. Das verwendete Fischfutter sollte aus Produkten lokaler Quellen kommen, einfach und kostengünstig hergestellt werden können, sowie keine Konkurrenz für die menschliche Ernährung oder für den Bedarf bei der Viehzucht darstellen und außerdem alle notwendigen Nährstoffe für die Fische enthalten.

Der Schwerpunkt dieser Arbeit liegt auf der Untersuchung der Akzeptanz der Tilapien auf die unterschiedlichen Futtermittel unter Anwendung der Videoanalyse. Außerdem wurde beobachtet ob sich das Futter für die Käfigfütterung eignet. Sinkt es zu schnell ab, kann es für die "cage-culture", bei der die Fische in Käfigen gehalten werden, nur bedingt verwendet werden.
Aus vorherigen Forschungsarbeiten [ASSMANN, 2009] ist bekannt, dass die Akzeptanz der Fische auf Biertreber (Nebenerzeugnis aus der Bierbrauerei) gut ist, die auf Blätter der *Tithonia diversifolia* und der *Ipomoea batatas* mäßig. Eine Futtermittelanalyse hat gezeigt, dass die einzelnen Bestandteile gute Proteingehalte aufweisen.
Für die unterschiedlichen Diäten wurden Blätter der Mexikanischen Sonnenblume (*Tithonia diversifolia*), Süßkartoffel (*Ipomoea batatas*) und Cassava (*Manihot esculenta*) gesammelt, getrocknet und zerkleinert. Anschließend wurden diese in unterschiedlichen Anteilen mit Biertrebern vermischt und unter Zugabe eines Bindemittels (Gelatine oder Agartine) pelletiert. Insgesamt wurden auf diese Weise 34 Mischungen produziert von denen 13 mittels Videoanalyse auf Akzeptanz getestet wurden.
In zwei Becken wurden jeweils fünf Fische mit einem Körpergewicht von 60-80g eingesetzt und 3 Mal täglich gefüttert. Mit einer vor den Becken installierten Videokamera wurden die Fütterungen in Sequenzen zu 8 Minuten gefilmt und analysiert. Die erhaltenen Daten dienten als Grundlage für die statistische Auswertung und Interpretation des Fressverhaltens. Als Referenz diente ein lokal gebräuchliches Futtermittel, das von den Fischen sehr gut angenommen wird.

Die Ergebnisse zeigen, dass die Akzeptanz der Fische auf ein bestimmtes Futter mit steigendem Anteil an Biertrebern zunimmt. Mischungen mit Blättern der Mexikanischen Sonnenblume werden jedoch nur schlecht angenommen. Sehr oft zeigt sich auch das Verhaltensmuster der Futteraufnahme, des Kauens und des anschließenden Ausspuckens bestimmter Partikel. Es konnte allerdings nicht festgestellt werden ob es sich hierbei um Biertreber oder zerkleinerte Pflanzenreste handelte.
Des Weiteren wurde beobachtet, dass sich das entwickelte Futter nur bedingt für die Käfighal-

tung eignet, da es sehr rasch absinkt. Hier sollte untersucht werden, ob es Möglichkeiten gibt die Pellets am Boden der Netze zu halten wie zum Beispiel durch Anbringung von “Bodenplatten”.

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Abbreviations

CO_2	carbon dioxide
E_i	expected frequency of a single action
$F(x), F_0(x)$	functions
$F_e(x)$	theoretically expected frequency function
$F_o(x)$	observed distribution- sampling function
H^+	hydrogen ion
H_0, H_1	hypothesis
$KMnO_4$	potassium permanganate
NH_3	ammonia
NH_4^+	ammonium
NO_2^-	nitrate
NO_3^-	nitrite
OH^-	hydroxide ion
O_i	observed frequency of a single action
α	alpha, standard deviation
χ^2	chi square
$^\circ$	angular degree
$^\circ$C	degree celsius
AT	atypical behavior
BOMOSA	**Bo**ku University, **M**oi University, **Sa**gana Aquaculture Center
BW	brewery waste
CAS	cassava leaves
cm	centimeter
CP	crude protein
df	degrees of freedom
DM	dry matter

DO	dissolved oxygen
FAO	Food and Agriculture Organization of the United Nations
kg	kilogram
MSF	mexican sunflower leaves
n.s.	not significant
PP	potassium permanganate
SPL	sweet potato leaves
T	typical behavior
t	tons
UNESCO	United Nations Educational, Scientific and Cultural Organization
WWAP	World Water Assessment Programme

Chapter 1

Introduction

In this chapter, data on the global and Kenyan food situation is given as well as conceptual explanations and consequences of malnutrition effects. Furthermore the role of aquaculture as weapon in the worldwide fight against malnutrition and poverty is clarified. In addition there is an explanation of the European Union funded BOMOSA project for establishing sustainable small- scale cage aquaculture in rural areas.

1.1 Global food and economic situation

"The first cause of hunger and malnutrition is poverty"
Hunger and malnutrition are still the largest global perspective problems, mainly relating to developing countries. Due to the rapid population increase, particularly in most developing countries where 62% of the people are living, there is growing doubt about the prospects in covering the rising global demand for food. Food production will need to increase to meet minimum requirements but at the same time agricultural land is declining [LOFTAS, 1995].

Nearly 30% of humanity in the developing world currently suffer from different forms of malnutrition. The well-recognized fundamental right to adequate food and nutrition remains deprived of a large proportion of the population in many countries even though we live in a world where the resources and know-how to improve the situation are given. The tragic consequences of malnutrition are death, disability and stunted intellectual as well as physical growth and as a result, retarded national socioeconomic development. Approximately 790 million people in developing countries and 34 million in developed countries, mainly women and children, are not eating sufficient food to meet their basic nutritional needs [FAO, 1999], [TACON, 2001a].

The Food and Agriculture Organization of the United Nations (FAO) defines food security as "*access by all people at all times to the food needed for a healthy and active life*" (World Bank, 1986). Ensuring food security requires that food is available regularly and that needy people can obtain it [CLAY, 2002].

The World Bank (WB) defines poverty as a "*multidimensional phenomenon, encompassing inability to satisfy basic needs, lack of control over resources, lack of education and skills, poor* *health, malnutrition, lack of shelter, poor access to water and sanitation, vulnerability to shocks, violence and crime, lack of political freedom and voice*" (World Bank, 2000). It is estimated that about one-fifth of the world's population is currently living in extreme economic poverty (means the availability of less than one US $ per day) [SUBASINGHE, 2005].

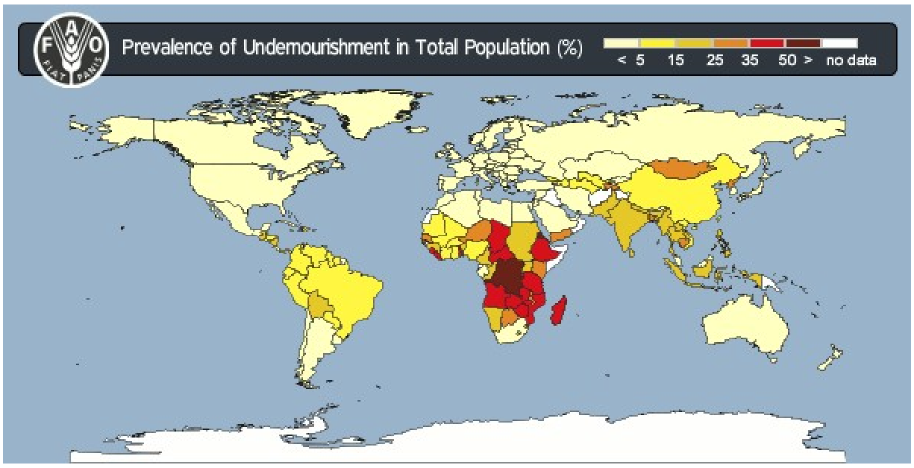

Figure 1.1: FAO Hunger map

Source: FAO Food Security Statistics, 06/03/2010
http://www.fao.org/economic/ess/food-security-statistics/fao-hunger-map/en/

Of the various global food production systems, aquaculture (farming of aquatic plants and animals) is an important tool in the global fight against malnutrition and poverty, seen mainly in developing countries. In general, it is seen as an important domestic provider of much-needed animal protein of high quality and other essential nutrients at affordable prices. Aquaculture also provides the ability to create employment, money and foreign exchange earnings. Food fish has a better nutritional profile than all terrestrial meat sources. In particular it has a high quality of animal protein and highly digestible energy, as well as an extremely rich source of omega-3 polyunsaturated fatty acids, vitamins and minerals [TACON, 2001b].

Small farmers (up to 70% of the population in many developing countries), especially in remote areas, encounter difficulties to access to markets and are further hindered by the lack of post-harvest facilities for perishable foods such as fish which can be used for personal consumption or sale [Miller, 2009].

Situation in Kenya

Only 18% of Kenyans territory exhibit areas with good agricultural potential but support 80% of the population (total population about 35.6 millions). A third of the population suffers undernourishment. It is estimated that the proportion of the population living below the national poverty line[1] has risen from about 49% in 1990 and up to 56% in 2003, meanwhile 23% live with less than 1 US $ per day. In 2004, it was estimated that more than 10 million Kenyans were

[1]National poverty rate is the percentage of the population living below the national poverty line deemed appropriate for the country by its authorities. In 2005 the national poverty line was at US $16 in rural areas and US $35 in urban areas per month.

experiencing chronic hunger [WAGAH et al., 2005].

1.2 Aquaculture

Aquaculture offers a stable, predictable and secure production of aquatic organisms like fish, shrimp, aquatic plants or algae which are grown under partial or fully controlled condition, just like “farming culture” in the water. Depending on the intensity of management a distinction of different types of aquaculture systems can be done:

- Extensive: natural productivity is corresponding to nutrient requirements of fish
- Semi-intensive: organic or inorganic pond fertilizers or supplementary feeding for yield increase are added
- Intensive: all nutrient requirements are met externally through formulated diets

In Africa the semi-intensive system dominates, feed costs take up more than 50% of operating costs of more intensive systems [LITI and MUNGUTI, 2003].

In sub- Saharan Africa, aquaculture is estimated to be 95% small- scale, with fish ponds integrated into the mosaic of agricultural activities. Approximately 82% of total world aquaculture production in 1998 were produced within developing countries. Only little or no statistical information concerning the scale and extent of rural or small-scale aquaculture within most developing countries exists because of the non-appearance in official statistics. [HAYLOR and BLAND, 2001].

Integrated farming systems

There are various forms of integrated aquaculture into other systems like small scale livestock-fish, agriculture- fish and irrigation ponds- aquaculture. “Outputs”, often called “wastes” or “byproducts” like excreta from chicken, ducks, pigs,... can be used to reduce costs on fertilizers and feeds in fish culture and raise benefits. The “wastes” can be entered in the pond to be recycled as organic fertilization and to improve productivity. Cages placed within ponds or reservoirs can also be viewed as integrated systems since the water resource has a better economically usage [GUPTA and NOBLE,] and [FUNGE-SMITH and PHILLIPS, 2001].
Overall ponds bring an increase in value of farming activities (water storage and supply for humans and livestock as well as irrigation). The obvious resulting of raising fish brings an increase in value of the water and provides improved nutrition for farm families [Miller, 2009].

Situation of aquaculture in Kenya

In Kenya, rural fish farming dates back to the 1920s. In recent years an increase in aquaculture production is noted with an outstanding peak in 2007 (see figure1.2, the exact values are shown in Appendix table A.1.

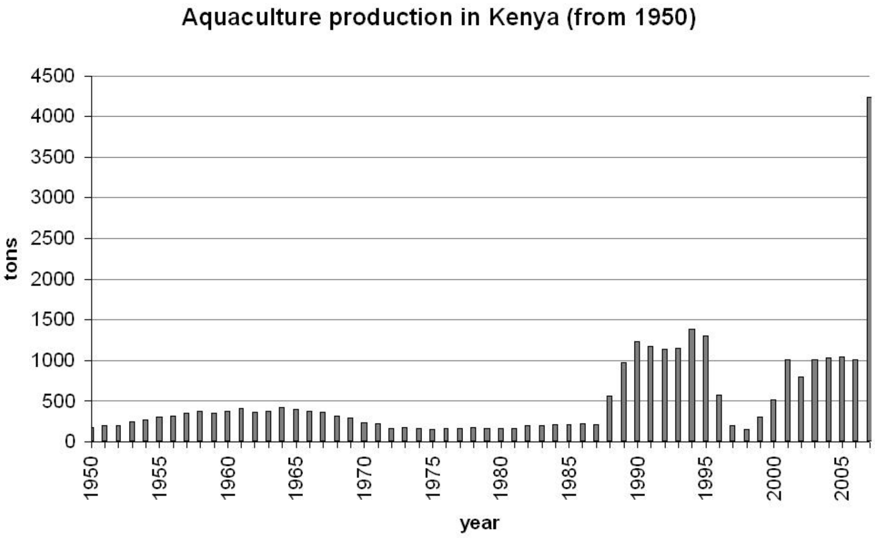

Figure 1.2: Aquaculture production in Kenya

Source: FAO Fishery Statistics[2], 06/03/2010
http://www.fao.org/fishery/countrysector/naso_kenya/en

Semi-intensive systems are the most represented type in Kenya, contributing more than 70% of the total production from aquaculture. The main aquaculture activities are practiced by poor households in inland areas including small-scale farming of tilapia [FAO, 2010].

In Kenya aquaculture has a share of only about 0.5% of total national fish production with some 10.400 small ponds owned by about 7.500 fish farmers. About 95% of fish farming in Kenya is small-scale. The current mean yield from small-scale fish farming is 1.000 kg/ha/year. Nile Tilapia, an indigenous species, is the most commonly cultured fish [FAO, 2005].

1.3 BOMOSA-

Integrating BOMOSA cage fish farming system in reservoirs, ponds and temporary water bodies in Eastern Africa

BOMOSA is a project funded by the 6^{th} Framework Program of the European Commission in cooperation with the University of Natural Resources and Applied Life Sciences (Universität für Bodenkultur, **BO**KU) in Vienna, the **Mo**i University in Kenya and the **Sa**gana Aquaculture Center in Kenya and was performed during a period of three years (October 2006 to September 2009).
In rural areas of Eastern Africa (Kenya, Uganda and Ethiopia) sustainable structures for the rearing of native fish like the Nile Tilapia (*Oreochromis niloticus*) are created with the attempt to associate aquaculture economically with existing agriculture. Local farmers will thus receive an additional economic mainstay, also the food situation will be improved, especially in terms of protein supply.

[2]FAO estimate: Data estimated from available source of information or calculation based on specific assumptions.

The main idea is to make previously unattractive waters in fishing (ponds, small dams, irrigation canals as well as temporary water during the rainy season) usable for fish farming. The core of the project are the easy usable cages (1.6x1.6x1.5m) which can be transported and handled without technical assistance and in which the fish grow and also can be harvested afterwards. Particular attention is paid to the fact that the fish are reared on locally available inexpensive fish feed and do not constitute competition for human consumption or for the needs of livestock. In the course of the project great importance was attached to the planning of proximity of the small fish farms to markets or processing facilities. Thus, the optimal locations were searched using satellite data, this information was linked with socio-economic data. Parallel to the development of farming methods training courses for local farmers were also organized.
An additional positive effect of Tilapia- farming is the decimation of the mosquito larvae in small waters which serve the fish as an additional food source.
[DREXLER and WAIDBACHER, 2009]

Chapter 2

Assignment of tasks and objectives

In the following chapter the problem outline is defined as well as the precise objectives of the work. The production of diets for the usage in aquaculture and the requirements for application in developing countries are explained too.

2.1 Problem definition

The main objective of fish farming is the conversion of food protein into fish protein. The protein sources in fish feed can be animal or plant origin, wherein the animal protein feed can rise sharply the production costs. The focus of interest is therefore to optimize the efficiency of the low cost plant proteins and the usage of farm wastes.
Formulated fish diets are relatively expensive and so not affordable for small-scale farmers, in contrast to commercial livestock feeds. As a result, in many developing countries agricultural by-products are used as organic inputs to ponds, as single ingredient diets or can be combined with other ingredients to complement the various nutritional properties, therefore offering the improvement of fish farming [LITI and MUNGUTI, 2003].

The main area of the present thesis was the low-cost production of fish feed using locally available resources in Kenya and was done in 2009 from beginning of February to end of April. Leaves of different plants were collected from the surrounding area and mixed with brewery waste (spent grain), a leftover of the brewery process. On the one hand the ingredients of the diets were analyzed in the laboratory on their content of crude protein, crude fiber, ether extract (crude lipid) and ash content (see [GUTMANN, prep]). On the other hand the produced diets were fed in aquariums and the behavior of fish observed and analyzed to determine whether the feed is accepted by them or not.
The previous year similar research, under the same project, has been done and served as the basis or rather was continued (see [ASSMANN, 2009] and [HEIMBERGER, prep]).

Hereafter the requirements of fish feed production for aquaculture in developing countries are listed:

- Simple and inexpensive manufacturing
- Local availability

- Usage of agricultural by-products
- No competition for human consumption or demand for livestock
- Should contain necessary nutrients for the fish

2.2 Research questions and objectives

In this work the main objective was to determine if the diets which were produced were accepted by the fish or refused through observation and analysis of the fish behavior during feeding.

Another question to be answered was whether there were visually observable differences in the descent rate of the pellets because of the fact that there were differences in the composition of the diets in relation to the distinct components of plant leaves and brewery waste as well as the usage of two different binders (gelatine and agartine) and its quantity. On this basis, a statement can be made whether it is suitable for feeding in cage-culture.

Another question which had to be evaluated was if there were preferences of the place of feed-intake (water surface, water column during the descent or the bottom of the tank).

Finally, a statement should be made whether the feed produced from locally available sources can be used for the small-scale aquaculture in Kenya.

Chapter 3

General aspects

In this chapter the experimental site with its facilities, like climate and vegetation, is presented. Furthermore Nile Tilapia, the used fish in the trial, and tilapia in general are described for a better understanding of the high usage in aquaculture and especially in developing countries due to its characteristics.

3.1 Trial site

The experiment was carried out in Sagana, at the Aquaculture Center, located in central Kenya in the higher-lying areas close to Mt. Kenya (5.199m above sea level) and near to the equator.

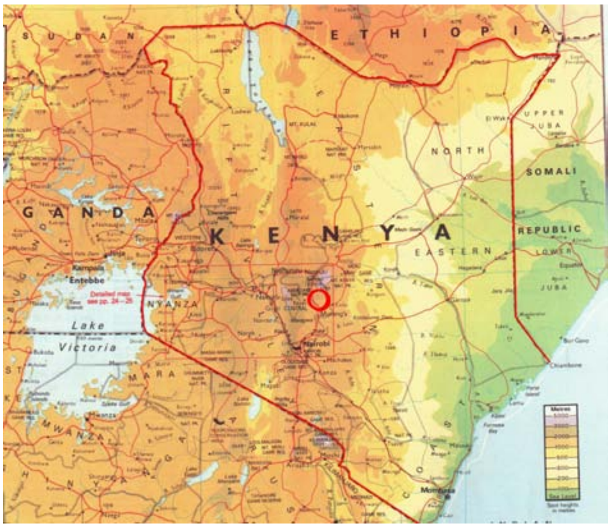

Figure 3.1: Map of Kenya

Source: http://www.blissites.com/kenya/bigmap.jpg, 08.01.2010

3.1.1 Climate and vegetation

Due to the huge differences in height (from the coast up to the high mountains over 5.000m) Kenya has different climatic zones with distinct temperature and humidity. The climate varies from tropical along the coast of the Indian Ocean with temperatures of 22-35 degrees to arid in the interior, and two-thirds of the country are covered by semi-desert or desert land. The desert regions in the north of the country are very dry and very hot with strong diurnal temperature fluctuations. There are two rainy seasons: the “long rains” that normally fall from April to May, and the “short rains” by the end of October to late November. The months of June, July and August are the cooler ones, January and February, the warmer months. Surface waters cover only two percent of Kenya’s total surface area [OKWARO et al., 2007] and [WWAP, 2006].

In the region maize, beans, sweet potato, arrow roots, rice, coffee and tea are mainly cultivated.

3.1.2 Sagana Aquaculture Centre

The Sagana Aquaculture Centre is located about 105 km northeast of Nairobi at 0°39’S and 37° 12’E, at an altitude of 1230 m above sea level and poses the largest of its kind in Eastern Africa. Established in 1948, it is now operated by the Fisheries Department of the Ministry of Livestock and Fisheries Development and occupies some 51 hectares of land with about 25 hectares under water. It uses water diverted from the Sagana River. The aquaculture farm serves as a research center, a training facility for fisheries personnel and fish farmers, as demonstration farm and fingerling supply center. The center contains a hatchery, a laboratory, a fish behavior observation room, holding tanks and integrated fish, livestock and poultry facilities. Concerning the fish species, nile tilapia, catfish and goldfish are bred. [LITI and MUNGUTI, 2003] and [FAO, 2005]

3.2 Nile Tilapia (*Oreochromis niloticus*)

Tilapia are freshwater fish belonging to the family of cichlids with approximately 1.000 species in the waters of tropical and subtropical areas of Africa, Madagascar, South America and Asia. The main distribution area is Africa with more than 700 species of cichlids.

Figure 3.2: Nile Tilapia (*Oreochromis niloticus*)

They are well suited for aquaculture, and here in particular for developing countries because of several characteristics:

- Rapid growth

- Compatibility for a wide range of environmental conditions (temperature, salinity, oxygen, pH)
- Captive breeding and short generation times
- Excellent feed converter

Because of these attributes, tilapia are also known as " aquatic chicken". They represent an important source of protein in the human diet, combined with low production costs and is now cultivated worldwide in over 100 countries [EL-SAYED, 2006].

3.2.1 Historical Background

Tilapia originated in the Nile region (Egypt) and it was assumed that it is cultivated about 4.000 years ago. A significant, worldwide dissemination of Nile Tilapia took place during 1960 - 1980. In 1978 Nile Tilapia was introduced into China, which today is the leading manufacturing country with more than half of the worldwide production. The evolution of hormonal sex-reversal techniques in the 1970s allowed to breed male monosex populations in a uniform and marketable size. The research on nutrition, culture system and market development led to a rapid increase of the industry since the mid-1980s. Nile Tilapia is the predominant cultured spices worldwide [RAKOCY, 2006].
In Kenya, the first attempts of Nile Tilapia breeding are dating back to 1920 [EL-SAYED, 2006].

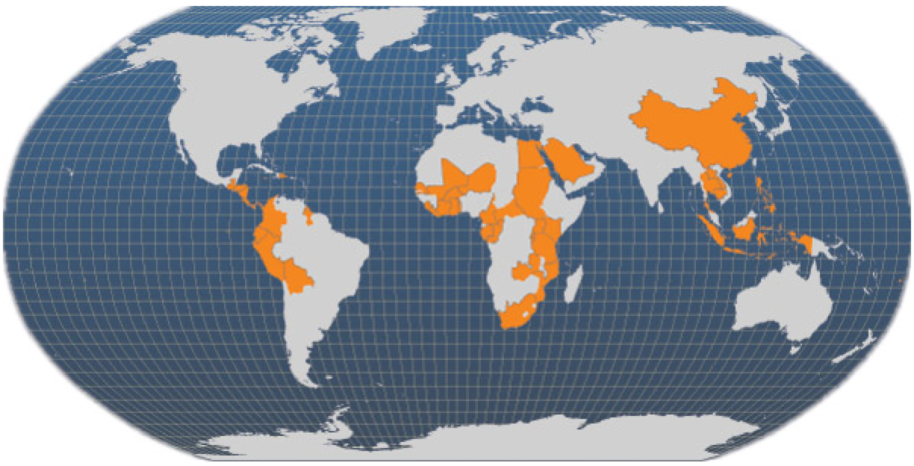

Figure 3.3: Main producer countries of Oreochromis niloticus

Source: FAO Fishery Statistics, 2006
http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/en#tcN9002B

3.2.2 Production statistics

The five largest producers of Nile Tilapia are China (806.000 t)[1], Egypt (200.000 t)[1], Philippines (111.000 t)[1], Thailand (97.000 t)[1] and Indonesia (72.000 t)[1] , followed by Lao People's Democratic Republic, Costa Rica, Ecuador, Colombia and Honduras [RAKOCY, 2006].
For the global aquaculture production for *Oreochromis niloticus* see figure 3.4, the exact values are shown in Appendix table A.2.

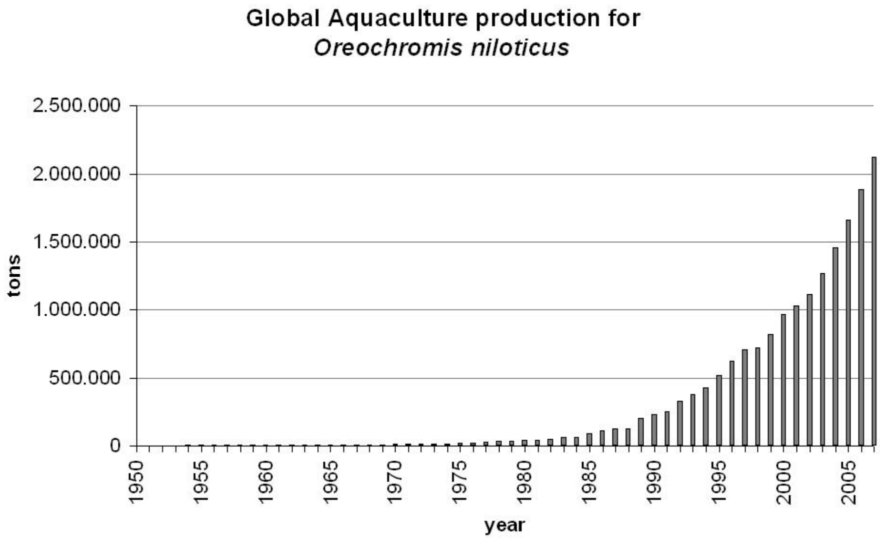

Figure 3.4: Global Aquaculture production for *Oreochromis niloticus*
Source: FAO Fishery Statistics[2], 06/03/2010
http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/en

3.2.3 Taxonomy

Nile Tilapia belongs to the family of cichlids, endemic to Africa, with more then 70 species described of tilapia. The taxonomic classification is puzzling because of the similarity and overlap of their morphological characteristics and the fact that many species of tilapia freely hybridize in nature [EL-SAYED, 2006].

The genus Tilapia is divided into different species depending on their reproductive behavior. All tilapia species are nest builders where fertilized eggs are guarded in the nest by a brood parent.

- *Tilapia* (substrate spawners)
- *Sarotherodon* (mouth breeders): Eggs are fertilized in the nest but are picked up in the mouth immediately and are held there through incubation and for several days after hatching. Distinction on whether males or females perform the mouthbreeding behavior.

[1] annual production 2003
[2] FAO estimate: Data estimated from available source of information or calculation based on specific assumptions.

- *Oreochromis*: only females practice mouth breeding
- *Sarotherodon*: either the male or both male and female are mouth brooders

Today, all commercially important tilapia outside of Africa belong to the genus *Oreochromis*, and more than 90% of all commercially farmed tilapia outside of Africa are *Nile Tilapia* [POPMA and MASSER, 1999].

3.2.4 Physical characteristics

Tilapia can be easily identified by an interrupted lateral line which is characteristic for the Cichlid family. Usually there are wide vertical bars down the sides with relatively subdued colours and with little contrast over the body colours. [POPMA and MASSER, 1999].
The body shape is characterized by a conventional, laterally compressed, deep shape. The dorsal and anal fins have hard spines and soft rays. The relatively large eyes gives them excellent visual capability [EL-SAYED, 2006].
Nile Tilapia can live longer than 10 years and reach a weight exceeding 5 kg [RAKOCY, 2006].

3.2.5 Reproduction

In the genus Oreochromis the breeding process starts when the male establishes a territory, prepares a nest and mates with some females. After a short mating ritual the female spawns the eggs, the male fertilizes them and then she holds and incubates the eggs in her mouth until the larvae hatch [POPMA and MASSER, 1999].
Depending on temperature, incubating and brooding is accomplished in 1 to 2 weeks. After releasing the fry, they may swim back into the females mouth if danger threatens. While breeding, they eat little or nothing. [RAKOCY, 2006].
Nile Tilapia matures at about 10 to 12 months, spawning begins when the water temperature reaches 24°C. When there is no cold period, during which spawning is suppressed, the female may spawn continuously [POPMA and MASSER, 1999].

3.2.6 Environmental requirements

Tilapia are very tolerant concerning high salinity, high water temperature, low dissolved oxygen, and high ammonia concentrations in comparison to most commonly farmed freshwater fish.

Salinity
All tilapia are tolerant to brackish water, Nile Tilapia grows well at salinities up to 15 ppt [POPMA and MASSER, 1999].
Some species can even grow and reproduce at very high water salinity. Normally the salt tolerance depends on tilapia species, strains and size, adaption time, environmental factors and geographical location [EL-SAYED, 2006].

Water temperature
The temperature is one of the most important factors concerning growth, reproduction, physiology and metabolism of tilapia. Due to the fact that tilapia are thermophilic fish, they show best performance when having water temperature of about 25- 30°C, but tolerating a range about 20

to 35°C. Tilapia can also survive at very low temperatures (7-10°C), but only for brief periods, and at about 16°C they stop feeding [EL-SAYED, 2006].

Dissolved oxygen concentration

Dissolved oxygen (DO) is a limiting environmental factor affecting fish feeding, growth and metabolism. Due to the photosynthesis, respiration and diel fluctuation the DO is varying. Tilapia can tolerate very low DO levels like 0.1-0.5 mg/l for varying periods of time and also levels near zero when they have access to surface air. Increasing water temperature reduces the rate of DO in the water and leads to increased respiration and oxygen consumption in tilapia. Handling stress also leads to significant higher oxygen demand [EL-SAYED, 2006].
It should be noted that tilapia ponds have a DO concentration higher than 1 mg/l. Lower levels over a longer period lead to a deterioration of growth, metabolism and disease resistance [POPMA and MASSER, 1999].

pH

Tilapia can tolerate a pH value ranging from 5 to 10 with an optimum of 6 to 9 [POPMA and MASSER, 1999].
Very low or high water pH can lead to behavioral changes, damage of gill epithelial cells, reduction in the efficiency of nitrogenous excretion and increased mortality [EL-SAYED, 2006].

Ammonia

The nitrogenous wastes of fish are mostly excreted via the gills in the form of ammonia which exists in two forms: ionized form NH_4^+, and unionized form (UIA) NH_3 which is much more toxic. An increasing pH leads to tenfold increase in the proportion of UIA. Stress signals of fish to high UIA concentration are for example the abrupt increase in swimming activity and darkening in body color are also typical [XU et al., 2005].
It is recommended by [EL-SHAFAI et al., 2004] that the UIA concentration is maintained below 0.1 mg/l. The toxic level of NH_3 with its negative effect on the growth of tilapia ranges from 0.07 to 0.14 mg/l. Longer exposure (a few weeks) to water with an UIA level greater than 1 mg/l induces losses, especially among fry and juvenile fish in correlation with low DO concentration [POPMA and MASSER, 1999].

Nitrite

Nitrite (NO_2) is toxic to many fish because it leads to disturbance of the physiological functions like the decrease of the capability of hemoglobin transporting oxygen; chloride ions reduce the toxity. Commonly, the nitrite concentration should be kept below 27 mg/l for freshwater culture [POPMA and MASSER, 1999]. Ammonia is oxidized into nitrite and then into nitrate through nitrifying bacteria (see also chapter 4.1). The addition of chloride to the water may protect tilapia from nitrite toxicity [EL-SAYED, 2006].

3.2.7 Stress and diseases

Tilapia are more resistant to distinct types of diseases than other commonly cultured fish, especially at optimum temperatures for growth. Stress, defined as "the internal equlibrium", increases the susceptibility to diseases. Causes for chronic stress are social interactions and hierarchies. Reducing the stress is very important to improve immunity and for disease control. Tilapia can be infected by parasites, viruses, fungi and bacteria as well as they can be subjected to various non-infectious diseases [EL-SAYED, 2006].

3.2.8 Feeding behavior

Tilapia are omnivorous grazers which feeds on a wide range of natural food like plankton, some aquatic macrophytes, planktonic and benthic aquatic invertebrates, larval fish, detritus and decomposing organic matter through "filtering". However they do not filter physically, the gills secrete a mucous that traps plankton which is then swallowed. Due to the extremely long intestine (usually six times the total length of the fish) plants can be easily digested and assimilated. With additional feeding, natural food organisms normally account for 30-50% of tilapia growth [POPMA and MASSER, 1999].
Because of the small stomach of tilapia and the characteristic continuous feeding, more frequent feeding is advised. The feeding (level, amount, frequency) is dependent on several factors like fish species, age and size, culture system and diet form (pellets, crumbles, mash, dry, moist, floating, sinking) [EL-SAYED, 2006].

3.2.9 Nutrition requirements

To increase the growth and production of fish farming, the feeding of prepared diets is an important factor. Dietary protein is a significant point for achieving efficient fish production and should be matched in dependence of the age and weight. Protein should be carefully formulated because it is the most expensive ingredient in prepared feeds. [ABDEL-TAWWABA et al., 2010] point out that fry tilapia show the highest growth at 45% crude protein (CP), while fingerling and advanced juvenile showed optimum growth performance at 35% CP.

Tilapia require, like other warm water fish, the same ten essential amino acids which are the building blocks of proteins [EL-SAYED, 2006].

For physiological functions like normal growth and development, energy production and protein sparing, structure and maintenance of cell membrane,... tilapia require dietary lipids. The requirements are not yet studied very well but approximately they need about 10 to 15% dietary lipids for optimum growth [EL-SAYED, 2006].

Carbohydrates are utilized by tilapia very well in comparison to carnivorous fish and are furthermore the cheapest source of dietary energy for humans, fish and domestic animals [EL-SAYED, 2006].

Vitamins are required only in small amounts in animal diets meanwhile minerals are inorganic elements and necessary for animals to maintain many metabolic functions like structure of hard skeletons, structure of soft tissues, osmoregulation. Moreover, minerals act as components of a lot of enzymes, vitamins, hormones and respiratory pigments. Concerning the exact vitamin and mineral requirements for tilapia, only little information is available [EL-SAYED, 2006].

Chapter 4

Methodology

The preparations that were needed for the experiment are explained in this chapter as well as a description of each component of the feed, the flow of feed production and a list of produced feed mixtures. Furthermore the experimental procedure, the data collection and data analysis are described.

4.1 Experimental set-up

For preparing the experiment, the tanks in the fish behaviour observatory room were arranged, filter pumps installed and fish (*Oreochromis niloticus*) stocked from the ponds. Ingredients for the feed were collected in the surroundings, prepared for further use and finally the feed was produced in the laboratory.

4.1.1 Fish behaviour observatory room

The fish behaviour observatory room is a small house which was built on the area of Sagana Aquaculture Center, Kenya to conduct the experiments for BOMOSA project (see figure 4.1). It consists of two concrete outside tanks and an interior room with glass panes to each tank for observing the fish (see figure 4.2). Both basins have a base area of 125 cm x 130 cm and a height of 130 cm. By dint of a direct water line from the water pump which is situated on the farm, each was filled with nearly 1.600 liters of bore whole water. Before using them they were cleaned with "Jik", a commercial bleach containing 3.5% Sodium hypochlorite which is a kenyan product for cleaning and disinfecting purposes. Afterwards the tanks were rinsed with pure water to remove the chemicals.

To guard the fish against the birds, the tanks were covered with a wooden framed grid (see figure 4.3).

From the inside it is not possible to have a view into the internal corners, so fish could hide there without being observed. Therefore wooden frames were built, covered with a net which was fixed with cable straps and put in the tanks with an angle of 45° to the walls. To protect the structures from uplifting they where ballasted with stones to hold them on the ground.

Figure 4.1: Observatory room with the bird protection lent aside

Figure 4.2: Observatory room indoors with the two filter pumps

Figure 4.3: Tank with net in the corners

For each basin an external filter pump (company Eheim, Germany) was used. They have several functions to fulfill like

- Mechanical filtering
- Biological filtering
- Oxygenation
- Movement of the water surface

After putting the lower lattice screen in the filter canister it was filled with around 2 kg of crushed charcoal, stuffed with cotton wool, covered with the top lattice screen and closed with the filter cover. Water from the bottom of the tank is suctioned by a higher dimensioned intake pipe which is covered by a strainer to avoid the incoming of bigger particles. Then the water is cleaned in the composed filter material and pumped back to the surface of the basin through the jet pipe with a smaller diameter. The difference in the hose size is for achieving a higher outlet pressure. Cotton wool has the task to retain pollutant particles like feed leftovers and

fish excrements. Charcoal with its high porosity has the ability to absorb smallest substances and is used to remove toxic agents out of the water.
The outtake pipe of the filter pump was situated a few centimeters under the water surface to avoid noise and to downsize stress for the fish [ASSMANN, 2009].

Fish excreta (feces, urine) and food particles can lead to an increase in nitrogen compounds and the formation of toxic substances. The degradation of organic compounds containing nitrogen is phased down by oxygen consumption (oxidative degradation). The initial breakdown products are toxic ammonia (NH_3) and the non-toxic ammonium (NH_4^+). The pH largely determines which of the two compounds are primarily formed. Ammonia is toxic with increasing pH. Bacteria (genus *Notrosomonas*), which are settled in the filter material convert ammonia to nitrite (NO_3^-), which is also toxic. In the last stage of reduction nitrite is converted to nitrate (NO_2^-) by bacteria of the genus *Nitrobacter*, which serves as a nutrient for algae and plants. The bacteria can exist only on appropriate filter materials with large surface area and sufficient supply of oxygen. The biological water treatment in the filter needs an initial period of several days to weeks. When cleaning the filter, one should never remove the entire filter material in order to conserve parts of the well established bacteria cultures [RIEHL and BAENSCH, 1991].

Every morning the tanks were cleaned with a special constructed siphon cleaner, shown in figure 4.4. It's a hose fixed on a stick to remove feed leftovers and fish excrements from the bottom of the basin. The operating mode is based on a pressure gradient. By filling the tube with water, closing the endings and situating one end at a lower level than the bottom of the tank, water is flowing due to the resulting low- pressure and is sucking the particles with it. After cleaning the basins they were filled up with fresh water again.

Besides every day in the morning the temperature and pH were measured to observe the quality of the water.

Figure 4.4: siphon cleaner

4.1.2 Fish stocking

For the trial in the observatory room 10 fish of the type Nile Tilapia *(Oreochromis niloticus)* were needed, 5 for each tank. They were taken out of the pond E5 on the Sagana fish farm on 21 February 2009. Due to their breeding habit it was important that only males were used for the feeding experiment because Nile Tilapia belongs to the species of mouth breeders. The females keep the eggs for around two weeks in their mouth; therefore they do not eat anything during this time. All picked fish had to have a weight between 60 to 80 grams. Before putting them in the tanks they were taken to the farms hatchery for a special treatment.

Treatment against infections and diseases

If Tilapia are exposed to stress situations or rather are kept in stress conditions, like too high stocking rate, they are more susceptible to get infected by parasites, bacteria and fungal caused diseases [EL-SAYED, 2006].

To control mortality caused by diverse infections, Potassium permanganate ($KMnO_4$) is widely-used in aquaculture. It is a useful fish disease treatment acting against a wide range of pathogenic germs. As being a strong oxidizing agent it can act as a disinfectant as well as to cure diseases, depending on the amount of added PP and the duration of stay of the fish in the "chemical bath". By its usage the external surfaces of fish, where disease problems normally begin, are "disinfected". Organic matter is oxidized such as undesirable organic matter like bacteria, parasites and fungus, but also desirable material like gill tissue and mucus [FRANCIS-FLOYD and KLINGER, 2002].

For the preventing disease treatment the fish were put in two glass tanks with a capacity of approximate 20 liters, two knife points of $KMnO_4$ were added and they were held there for 20 minutes. Afterwards they were removed to the observatory room.
Concerning the amount of added Potassium permanganate and the duration of treatment there can be found a lot of different assignments in literature. [FRANCIS-FLOYD and KLINGER, 2002] suggest for example a concentration of 2 mg/l as a longterm-bath (at least four hours) for common cichlids and 10 mg/l for short-term bath (30 minutes) meanwhile [MCMILLAN, 2009] advise to use 1-2 mg/l during 20-60 minutes and a 10 minutes-bath for a treatment against viruses with a concentration of 50 mg/l.

It is important that the transport of the fish from the pond to the hatchery and after the treatment to the tanks in the observatory room is performed quickly to minimize the stress situation. During the first stocking they stayed too long in the transport bucket and also in the small aquariums, so they were already infected when they came to the observatory room and most of them died within several days. At the second stocking they were immediately brought to the hatchery and promptly after treatment delivered to the tanks.

4.2 Feed

The assortment of feed can be based on conclusions from previous research works. Therefore it is known that "Brewery Waste" (a by-product in the brewery process) and sweet potato leaves are accepted by the fish meanwhile mexican sunflower leaves are refused though they are high in protein. For the production of feed, leaves of Sweet potato, Mexican sunflower and Cassava were collected in the surroundings of Sagana, dried in the sun and choped. Afterwards they were mixed in different proportions with brewery waste, binding agent was added and this mixture was pelletized. To prove the acceptance of the fish the various feeding stuffs were fed to the fish.

As binders gelatine (derived from the collagen inside animal's skin and bones) and agartine (derived from seaweed) were used. It had to be investigated whether the binding agents show different descent rates of the pellets. If they fall too fast, they are not applicable in the "cage culture", where fish are kept in cages in a pond. The feed would fall within short time through the net of the cage ground; hence it would no longer be accessible for the fish and also would lead to a deterioration of water quality.

In the next chapters the feed categories inclusive the produced mixtures are presented with their characteristics and their substances of content. All the values in the tables are given in % of the dry matter (DM). For further information concerning the composition of the several mixtures see [GUTMANN, prep]. A total of 34 feeding stuffs were produced of which 13 were subjected to an experimental analysis in the observatory room.

4.2.1 "Sagana Diet"

"Sagana Diet" is the daily used feed on the fish farm and is highly accepted by the fish. Therefore it acts as reference in the subsequent analysis. The diet consists of 25% cottonseed meal, 12% freshwater shrimp (*Caridinea niloticus*) and 63% wheat bran. The composition is shown in table 4.1.

	Sagana mixture
Crude protein	28.5
Ether extracts	5.6
Nitrogen free Extracts	43.2
Crude fiber	14.8
Ash	7.9

Table 4.1: Proximate composition of the diet Sagana (after [Munguti et al., 2009])

4.2.2 Brewery waste

Brewery waste (spent grain) is a simple low-cost agricultural by-product that accrues during the brewage process. Since the grains contain important nutrients and trace elements they are an excellent feed which has no exposure to environmental toxins and fungi and has a high percentage of usable proteins.
It is also one of the promising protein source by- products for fish diets in place of fish meal [ZERAI et al., 2008].
Brewery waste as a component of the produced feed mixtures, was purchased from the local "Tusker"- brewery near the Kenyan capital Nairobi. For the production of fish feed only small amounts are required in comparison to livestock farming, therefore it is not in competition with it. For the composition of Brewery waste see table 4.2.

	Crude protein	Crude fiber	Ether Extract (Crude lipid)	Ash content
Brewery Waste	28.0	15.3	15.2	5.2

Table 4.2: Proximate composition of "Brewery waste" in % of DM after [GUTMANN, prep]

4.2.3 Sweet potato leaves based feed

The agricultural crop Sweet potato (*Ipomoea batatas*) belongs to the family of *Convolvulaceae* and is a tuberous- rooted plant, usually grown as an annual and drying back to ground each year. The stems are forming a running vine up to four meters long. Especially the roots are used as food but partly also the leaves. *Ipomoea batatas* is native to the American Tropics but nowadays also introduced and cultivated in many other tropical and subtropical countries. Well-adapted to tropical and subtropical climates it is reported that sweet potato is achieving the best growth in average temperatures of 24 degrees, with sufficient sunshine and adequate water supply during the growing season where the average frost-free growing season is at least 5 months [DUKE, 1998].
In Kenya, the sweet potato growing is mainly focused in the West but also in the coastal areas and in central Kenya. It represents an important secondary food crop in addition to the basic foods based on cereals, especially as the maize. A big advantage is the ability to adapt to a wide range of climatic conditions, which makes the cultivation in many parts of the country possible [GTZ, 1998]. For the composition of Sweet potato leaves see table 4.3.

	Crude protein	Crude fiber	Ether Extract (Crude lipid)	Ash content
Sweet potato leaves	25.7	20.2	9.8	15.3

Table 4.3: Proximate composition of “Sweet potato leaves” in % of DM after [GUTMANN, prep]

4.2.3.1 Mixtures with Sweet potato leaves

Sweet potato leaves (SPL) and brewery waste (BW) were weighed and mixed in different proportions to each other. In table 4.4 the different produced mixtures are shown. For example for the feed SG30 70% of brewery waste and 30% of sweet potato leaves were used, for the feed SG40 60% of brewery waste and 40% of sweet potato leaves and so on. Besides in addition to the gravimetric mixtures a volumetric mixed feed was prepared with equal volume fractions. This type of composition is particularly easy to produce, since no measuring instrument is needed apart from a can, bucket or the like. All the different mixtures were each made with the binder galtine and agartine.

Gelatine	BW [%]	SPL [%]	mixture
gravimetric	70	30	SG30
	60	40	SG40
	50	50	SG50
	40	60	SG60
	30	70	SG70
volumetric	50	50	SGV

Agartine	BW [%]	SPL [%]	mixture
gravimetric	70	30	SA30
	60	40	SA40
	50	50	SA50
	40	60	SA60
	30	70	SA70
volumetric	50	50	SAV

Table 4.4: Produced mixtures of Sweet potato leaves with Brewery waste

4.2.4 Mexican sunflower leaves based feed

The Mexican Sunflower (*Tithonia diversifolia*) belongs to the family of *Asteraceae* and is a bushy plant with a height of up to 3 meters. It is originated in South America and can be found on roadsides and as a farm hedge species in tropical Africa too. The plant grows very quickly, even under unfavourable circumstances. Despite the good nutrient and protein content it is hardly eaten by animals due to the bitter taste. The Mexican sunflower is believed to kill parasites of the gastro- intestinal tract, so it is used as “medicine” [WANJAU S. and R., 1998].

	Crude protein	Crude fiber	Ether Extract (Crude lipid)	Ash content
Mexican sunflower leaves	30.4	12.0	14.2	14.7

Table 4.5: Proximate composition of “Mexican sunflower leaves” in % of DM after [GUTMANN, prep]

4.2.4.1 Mixtures with Mexican sunflower leaves

The various mixtures of Mexican sunflower leaves (MSF) with Brewery waste (BW) were prepared as described in chapter 4.2.3.1. For the different produced feed combinations see table 4.6.

Gelatine	BW [%]	MSF [%]	mixture
gravimetric	70	30	MG30
	60	40	MG40
	50	50	MG50
	40	60	MG60
volumetric	50	50	MGV

Agartine	BW [%]	MSF [%]	mixture
gravimetric	70	30	MA30
	60	40	MA40
	50	50	MA50
	40	60	MA60
volumetric	50	50	MAV

Table 4.6: Produced mixtures of Mexican sunflower leaves with Brewery waste

4.2.5 Cassava leaves based feed

The Cassava (*Manihot esculenta*) belongs to the family of *Euphorbiaceae*. Maniocs are perennial shrubs with a height from 1.5 to 5 meters; the tubers are used mainly as food and occasionally the leaves as a vegetable. Cassava has its origins in Brazil and Paraguay and is nowadays cultivated as staple food in many parts of Africa and the humid tropics. It requires at least 8 months of warm weather to produce a crop and is traditionally grown in savanna climate but also can sprout in extremes of rainfall. In dry seasons they get rid of their leaves to conserve moisture and start producing new leaves when rain resumes. All plant parts contain cyanogenic glucosides with the highest concentrations in the leaves [O’HAIR, 1995].

4.2.5.1 Mixtures with Cassava leaves

The various mixtures of Cassava leaves (CAS) with Brewery waste (BW) were prepared as described in chapter 4.2.3.1. For the different produced feed combinations see table 4.8.

	Crude protein	Crude fiber	Ether Extract (Crude lipid)	Ash content
Cassava leaves	28.8	16.9	15.0	7.5

Table 4.7: Proximate composition of "Cassava leaves" in % of DM after [GUTMANN, prep]

Gelatine	BW [%]	CAS [%]	mixture
gravimetric	70	30	CG30
	60	40	CG40
	50	50	CG50
	40	60	CG60
	30	70	CG70
volumetric	50	50	CGV

Agartine	BW [%]	CAS [%]	mixture
gravimetric	70	30	CA30
	60	40	CA40
	50	50	CA50
	40	60	CA60
	30	70	CA70
volumetric	50	50	CAV

Table 4.8: Produced mixtures of Cassava leaves with Brewery waste

4.3 Expermimental procedure

In the following chapter the implementation of the experiment is explicated, in particular the feeding and filming procedure as well as the control of water quality.

4.3.1 Feeding and recording

The fish were fed three times a day. The daily quantity of feed per fish was 3% of their body weight. The total quantity of feed per day was calculated using formula (4.1). Then the result was divided by two, as the fish were kept in two tanks. To obtain the amount per feeding, the result was again divided by three.

$$Feeding\ amount\ per\ day = \frac{total\ body\ weight\ of\ all\ fish \times 3}{100} \tag{4.1}$$

The total weight of all fish at the beginning was 733 grams, 3% of them resulting 22 grams of feeding amount per day. Divided by two and again by three, the calculated amount per tank and per feeding event resulted in 3.7 grams.

The fish were fed five days with a produced feed mixture. The first two days were used for acclimatization to the new feed, the remaining three days the feeding behavior was filmed. Thereafter the fish got for two days the feed "Sagana" for "neutralization", and then again five days a new mixture, etc.

During filming, sequences of eight minutes per feeding unit were taken which were then statistically analyzed (see chapter 5). Every filming sequence was started when the feed was thrown in. The recordings were made with a Panasonic NV-GS60EG digital video camera. Afterwards the individual films have been transferred to the program "Pinnacle Studio Media Suite" (version 10) on a laptop.

The feeding took place every day at 8:00, 11:30 and 16:30. From noon, the lighting conditions were bad for filming, so the period between second and third feeding was longer than antemeridian . In addition, the tanks were covered in the afternoon, to minimize the back-light caused by the strong sunlight.

4.3.2 Water quality control

The parameters temperature and pH-value in the two tanks were measured every day at 07:30 in the morning. Unfortunately the oxygen meter did not work due to a technical defect. The temperature was measured with a digital thermometer, the pH-value with a pH-meter of the company Voltcraft. The results are shown in chapter 5.

4.4 Data capture and evaluation

Once the feeding recordings were transferred to the computer, the individual film sequences were analyzed to obtain the data for the final evaluation as described in this chapter. As soon as the data were available they were analyzed by using statistical methods in order to make a statement about the experimental results.

4.4.1 Film evaluation

For each feed a separate Excel sheet has been prepared; Table 4.9 shows an example of such a film analysis generated with Excel. From the eight-minute film sequences the individual behaviors of each fish, expressed by so-called activity codes (see table 4.11), were noted in order of their occurence.

Table 4.9 shows an extract of the data analysis of the gravimetric prepared mixture with 40% Cassava leaves and 60% Brewery waste, in use of the binder agartine. In column (1), “mixture” the code of the used feed mixture is listed, in column (2) the consecutive number of the single actions. The next column (3) shows the date when the recording took place. The letters “L” or “R” stand for one of the two tanks (left one or right one) where the fish were kept. The numbers one, two or three (column 5) indicate the time of recording (morning, noon, afternoon) as it is shown in table 4.10. The numbers which are recorded in column 6 are showing the serially numbering of the single actions according to the individual eight- minute sequences. To identify the single fish, every one was named by a capital letter (column 7). In the last column (8) the various activities (see behavior codes table 4.11) of each fish are listed as lower case letters in chronological order of occurrence.

Table 4.11 is highlighting the different observed behaviors of the fish. Column (1) is listing so called “behavior codes”, alphabetically arranged lowercases, for the single activities (action/ habit) which are listed in detail in column (2).

4.4.2 Data evaluation

The created tables (Excel sheets) of every recorded diet were transferred to the statistical program SPSS 15.0 for windows. With the program it was possible to arrange the data according to various aspects and to carry out different calculations. Thus, for example, the individual diets could be combined to feed groups (all diets based on Cassava leaves, Sweet potato leaves or based on Mexican sunflower leaves). Furthermore an additional evaluation could be created for the location of feed intake, the activities of individual fish, the differentiation based on the feeding behavior (for instance preference for fodder or algae), distribution of activities in general or rather feeding activities in relation to the daytime or investigation for the first five performed

Table 4.9: Extract of the data analysis for one mixture

(1) mixture	(2) consec. nr.	(3) date of record	(4) tank	(5) time	(6) action nr.	(7) fish	(8) action/ habit
CA40	1	25/04/2009	L	1	1	E	a
CA40	2	25/04/2009	L	1	2	K	a
CA40	3	25/04/2009	L	1	3	B	a
CA40	4	25/04/2009	L	1	4	E	a
CA40	5	25/04/2009	L	1	5	K	d
CA40	6	25/04/2009	L	1	6	K	f
CA40	7	25/04/2009	L	1	7	W	d
CA40	8	25/04/2009	L	1	8	B	a
CA40	9	25/04/2009	L	1	9	B	f
CA40	10	25/04/2009	L	1	10	G	a
CA40	11	25/04/2009	L	1	11	G	g
CA40	12	25/04/2009	L	1	12	G	m
CA40	13	25/04/2009	L	1	13	W	f
CA40	14	25/04/2009	L	1	14	W	g
CA40	15	25/04/2009	L	1	15	W	m
CA40	16	25/04/2009	L	1	16	G	a
CA40	17	25/04/2009	L	1	17	G	f
CA40	18	25/04/2009	L	1	18	G	f
CA40	19	25/04/2009	L	1	19	W	w
CA40	20	25/04/2009	L	1	20	W	f
CA40	21	25/04/2009	L	1	21	W	a
CA40	22	25/04/2009	L	1	22	W	m
CA40	23	25/04/2009	L	1	23	K	f
CA40	24	25/04/2009	L	1	24	K	a
CA40	25	25/04/2009	L	1	25	W	w
CA40	26	25/04/2009	L	1	26	K	f
CA40	27	25/04/2009	L	1	27	W	w
CA40	28	25/04/2009	L	1	28	K	w
CA40	29	25/04/2009	L	1	29	K	f
CA40	30	25/04/2009	L	1	30	K	l
CA40	31	25/04/2009	L	1	31	W	f
CA40	32	25/04/2009	L	1	32	K	f
CA40	33	25/04/2009	L	1	33	K	l
CA40	34	25/04/2009	L	1	34	K	f
CA40	35	25/04/2009	L	1	35	W	w
CA40	36	25/04/2009	L	1	36	K	f
CA40	37	25/04/2009	L	1	37	K	f
CA40	38	25/04/2009	L	2	1	E	a
CA40	39	25/04/2009	L	2	2	K	a
CA40	40	25/04/2009	L	2	3	B	a
CA40	41	25/04/2009	L	2	4	E	a
CA40	42	25/04/2009	L	2	5	B	d
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 4.10: Evaluation codes for recording time

time	code
08:00	1
11:30	2
16:30	3

Table 4.11: Evaluation codes for fish behavior, modified according to [ASSMANN, 2009]

(1) code	(2) action/ habit
a	snapping feed from water column
b	spitting feed/algae
c	no feeding, swimming around
d	feed is too big/trying to snap
e	snapping small particles
f	snapping feed from bottom
g	chewing
h	sniffing
i	snapping feed from surface
j	snapping feed which was spit out before
k	does not catch feed which was spit out before
l	collecting particles from the bottom
m	“spraying” (spitting particles)
n	grazing the surface, filtering
o	losing the feed
p	snapping fish excrements
q	scraping algae of the wall
r	scraping algae from bottom
s	scramble for feed
t	snapping lost feed again
u	turning away from feed
v	feed is snapped by other fish
w	chasing another fish
y	spitting crushed pellet
z	struggle with too big/hard feed

activities per feeding. After analyzing and sorting the data in SPSS, they were again partially transmitted to Excel for producing charts.

4.4.2.1 Statistical test procedures

The evaluation was subjected to a global test (for total distribution) and a local test (for every single activity).

Global Test

As a global test the chi-square test (χ^2-test) was used. It is testing whether the theoretically

expected frequency distribution $F_e(x)$ fits to the in the experiment observed distribution- sampling distribution- $F_o(x)$ or if there are significant variations.
One can say that the observed frequencies (the number of observations of a particular occurrence) are compared to the expected frequencies under the validity of the null hypothesis (H_0). So those frequencies of occurrence are meant, which would be expected if the variable is followed by examining the hypothetical distribution, so if H_0 was true. When the frequencies in the observed present sample deviate "too strong" from the expected frequencies, the null hypothesis is rejected and the alternative hypothesis is valid (H_1), see below (1) Hypothesis.
With a sufficiently large number of observed frequencies the test statistic is nearly distributed χ^2 with n-1 degrees of freedom. If the null hypothesis is true, the difference between the observed and the theoretically expected frequency should be small. At a certain significance level of alpha (α), H_0 is rejected if applicable $\chi^2 > \chi^2_{tab}$ (α; df), means if the value obtained from the sample of the test statistic is larger than the (1-α)-quantile of the χ^2-distribution with n - 1 degrees of freedom (df); α means the maximum error probability. Chi^2 is calculated using formula (4.4). The decision criteria of using or rejecting the null hypothesis is listed below point(3) Comparison. There are tables of the χ^2_{tab}-quantiles ("critical values"), depending on the number of degrees of freedom and the desired level of significance α (see Appendix table A.3).

(1) Hypotheses

$$H_0 : F_e(x) = F_o(x) \tag{4.2}$$

$$H_1 : F_e(x) \neq F_o(x) \tag{4.3}$$

(2) Test statistics

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} = (\sum \frac{O_i^2}{E_i}) - N \tag{4.4}$$

(3) Comparison

$\chi^2 \leq \chi^2_{tab} \Rightarrow H_0$ (no deviation between observation and expectation)

$\chi^2 > \chi^2_{tab} \Rightarrow H_1$ (significant deviation), that is to say $F_o(x)$ can not be adapted to $F_e(x)$

[KÖHLER et al., 2002]

Local Test/ Typical- Atypical behavior

To determine whether a result is significant, the differences between expectation and observation, known as residuals (see equation 4.5), are calculated. A significant difference exists if the standardized residual has a value greater than 2.56. Further limits are listed in table 4.12.

Table 4.12: Limits of the probability of error [BÜHL, 2008]

standardized residuals	Significance level (α)
≥1.67	0.10 (10%)
≥1.96	0.05 (5%)
≥2.56	0.01 (1%)
≥3.30	0.001 (0.1%)

However, this applies only if the expected frequency is at least five.
The standardized residuals, that are, by the square root of the expected frequencies of the divided residuals under the assumption of statistical independence of row i and column j (if no dependency exists between the behavior and the certain diet) [BÜHL, 2008].

$$SR_{ij} = \frac{(O_{ij} - E_{ij})^2}{\sqrt{E_{ij}}} \tag{4.5}$$

The observed frequency (O_i) is the actual observed number of occurrences of a particular behavior. The expected frequency (E_i) is the theoretically expected frequency if all behavior would occur equally often (uniform distribution) and is calculated by the sum of observations divided by the number of observed behaviors. Depending on the adoption of the significance levels a certain behavior is judged as **typical (T)** if the residual is positively above the uniform distribution or **atypical (AT)** when the residual is negatively distributed.

Chapter 5

Results

In this chapter the results of the water quality and the analysis of the feeding behavior are presented. After a brief overview of the different produced and analyzed diets, the individual results are shown by using diagrams and tables.

5.1 Water quality parameters in the observation tanks

In figure 5.1 the daily course of measured temperature (recorded from 02.03.2009 to 25.04.2009) is shown. Since the two tanks were outside the building, they were exposed to the weather conditions. Daily temperature variations are due to higher rainfall and different amounts of refilled bore whole water in the course of daily tank cleaning. The trend line shows a decrease in temperature due to the rainy season and the associated air temperature.

Because of its location the left tank has a slightly higher temperature on a daily basis as it is exposed to sunlight longer than the right tank. The average temperature in the left tank is at 25.0°C on the right at 24.8°C.

Nile Tilapia shows a wide range of acceptance concerning the water temperature, which is of 20°C to 35°C. The optimum for rapid growth is of 25°C to 30°C [EL-SAYED, 2006].

The pH value expresses the degree to which an aqueous solution is acid, neutral or basic (alkaline). The reason for this reaction are hydrogen ions (H^+) and hydroxide ions (OH^-). These are in the water present in low concentrations and caused by the dissociation of water molecules. The pH value is almost exclusively determined by the interaction of carbonate and carbon dioxide (CO_2). CO_2 causes a decrease in pH value and is produced for example during the respiration of fish [HAGENAUER et al., 1992].
The records of the two basins tends to show a slight decline in pH value (see figure 5.2), the average rate in the two pools were each of pH 7.1.

Nile Tilapia tolerate a range of water pH of 4 to 11. Higher or lower pH value may lead to damage of gill epithelial cells, behavioral changes, reduction in the efficiency of nitrogenous excretion and increased mortality [EL-SAYED, 2006].

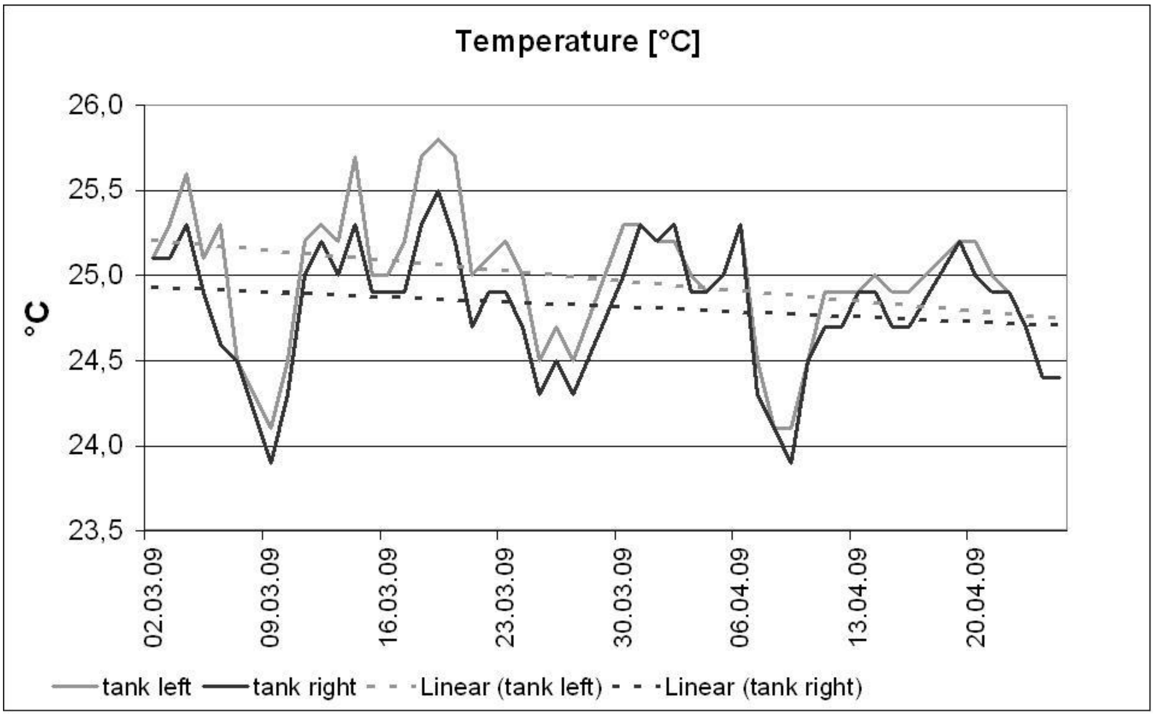

Figure 5.1: Chronological sequence of the water temperature and the corresponding trend lines

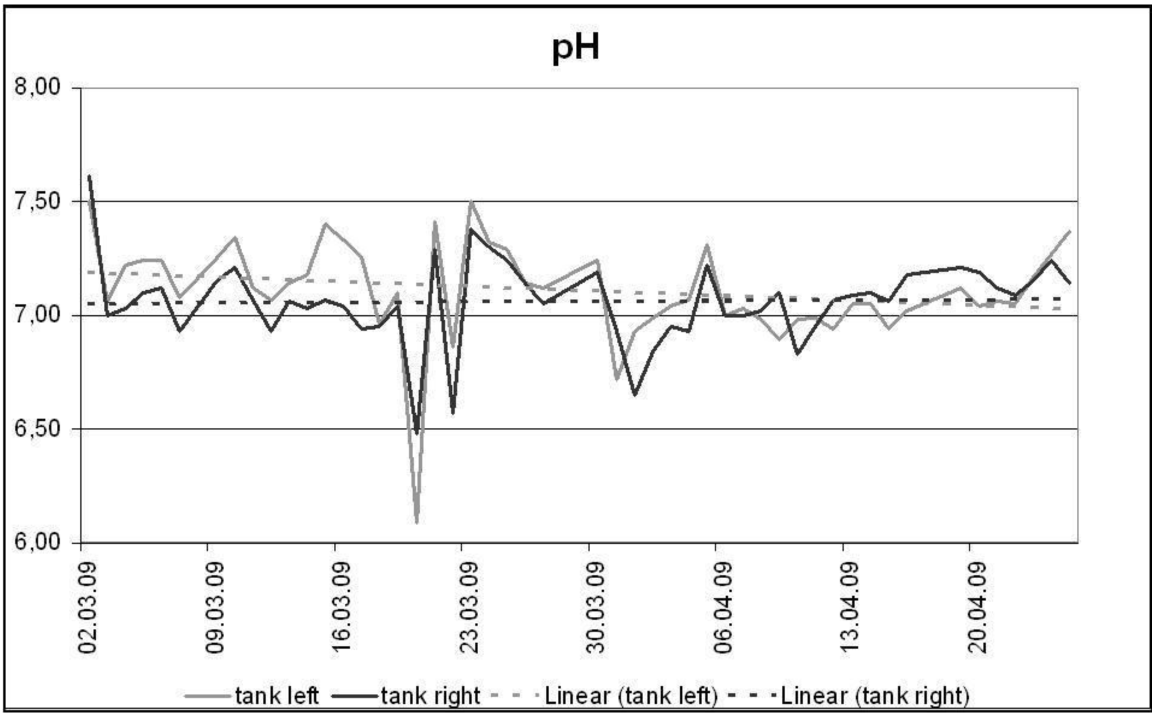

Figure 5.2: Chronological sequence of the pH value and the corresponding trend lines

5.2 Feeding behavior

In this section the results concerning the acceptance and typical or atypical fish behavior of the 14 tested feed mixtures are presented (the diet "Sagana" which was used as a reference and 13 self-produced diets). Figure 5.3 is showing an overview of all produced diets, with the analyzed ones highlighted in gray. The numbers are presenting the share, expressed in percent, of the various components (breweries waste mixed with the leaves of in chapter 4 mentioned plants) of feed mixture.

CASSAVA

Gelatine	BW	CAS	code
gravimetric	70	30	CG30
	60	40	CG40
	50	50	CG50
	40	60	CG60
	30	70	CG70
volumetric	50	50	CGV

Agartine	BW	CAS	code
gravimetric	70	30	CA30
	60	40	CA40
	50	50	CA50
	40	60	CA60
	30	70	CA70
volumetric	50	50	CAV

MEXICAN SUNFLOWER

Gelatine	BW	MSF	code
gravimetric	70	30	MG30
	60	40	MG40
	50	50	MG50
	40	60	MG60
volumetric	50	50	MGV

Agartine	BW	MSF	code
gravimetric	70	30	MA30
	60	40	MA40
	50	50	MA50
	40	60	MA60
volumetric	50	50	MAV

SWEET POTATO

Gelatine	BW	SPL	code
gravimetric	70	30	SG30
	60	40	SG40
	50	50	SG50
	40	60	SG60
	30	70	SG70
volumetric	50	50	SGV

Agartine	BW	SPL	code
gravimetric	70	30	SA30
	60	40	SA40
	50	50	SA50
	40	60	SA60
	30	70	SA70
volumetric	50	50	SAV

Figure 5.3: Overview of all produced diets

Below, all individual results of each diet are shown, using graphics and tables. This is followed by the presentation of the three feed classes, which means that all Cassava leaves, Mexican sunflower leaves and Sweet potato leaves based feeds are summarized.
It is noted that not the same fish were used throughout the entire time of the experiment.
In the various tables, like for example 5.1, the first two columns are pointing out the habits/activities of the fish. Column 3 shows the observed frequencies ("o"), column 4 the expected frequencies ("e") for uniform distribution and column 5 the calculated test statistic ("u"). In the penultimate column it is identified whether there was analyzed a typical (highlighted in light gray) or atypical (highlighted in dark gray) behavior concerning the individual activities. The last column is giving the observed frequencies as percentage. Furthermore the number of total activities can be read in the last line.

5.2.1 CA30

For the diet CA30 typical behaviors are “snapping feed from water column” (9.1%), “snapping feed from bottom” (31.4%), “chewing” (19.3%) and “spitting particles” (20.2%) as it is shown in table 5.1 and figure 5.4. Most activities were observed in feed intake at the bottom (31%). This is in part due to the rapid sinking of the pellets. During the eight-minute recording feed intake was continuously observed and usually the cycle of “feed snapping from the bottom”, followed by a longer period of “chewing” and then “spitting smaller feed particles” was observable. “Collecting particles from bottom” (4.1%), “scraping algae” (5.0%) and “chasing another fish” (4.6%) were not accounted so many times and are therfore not significant.

Table 5.1: CA30, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	71	43.11	4.25	T	9.1
b	spitting feed/ algae	7	43.11	-5.50	AT	0.9
d	feed is too big trying to snap	4	43.11	-5.96	AT	0.5
e	snapping small particles	0	43.11	-6.57	AT	0.0
f	snapping feed from bottom	244	43.11	30.60	T	31.4
g	chewing	150	43.11	16.28	T	19.3
i	snapping feed from surface	0	43.11	-6.57	AT	0.0
l	collecting particles from the bottom	32	43.11	-1.69	n.s.	4.1
m	spitting particles through gills	157	43.11	17,35	T	20.2
n	grazing the surface, filtering	0	43.11	-6.57	AT	0.0
o	losing the feed	10	43.11	-5.04	AT	1.3
p	snapping fish excrements	1	43.11	-6.41	AT	0.1
q	scraping algae of the wall	39	43.11	-0.63	n.s.	5.0
r	scraping algae from bottom	17	43.11	-3.98	AT	2.2
t	snapping lost feed again	2	43.11	-6.26	AT	0.3
u	turning away from feed	3	43.11	-6.11	AT	0.4
w	chasing another fish	36	43.11	-1.08	n.s.	4.6
y	spitting crushed pellet	3	43.11	-6.11	AT	0.4
	total	776	776.00			100.0

Note: e = 776/18 = 43.11 (uniform distribution)
Global Test (for total distribution): χ^2 = 1915.7; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

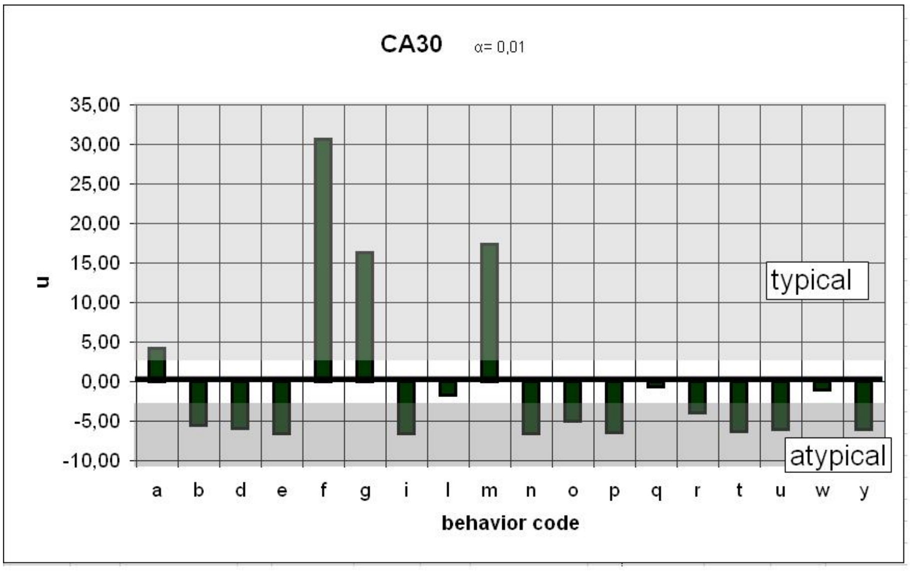

Figure 5.4: CA30, graphical presentation of the significance

5.2.2 CA40

CA40 acts very much as the before mentioned diet CA30. Likewise it turned out that "snapping feed from water column" (17.5%), "snapping feed from bottom" (29.0%), "chewing" (14.6%) and "spitting particles" (21.5%) are detected as typical behaviors as it can be read in table 5.2 and figure 5.5. "Scraping algae of the wall" (1.8%) was only observed with a percentage of 1.8, means that the diet is better liked than algae and therefore a higher number of this noted activity would constitute an undesirable behavior. No significant habits are "collecting particles from bottom" (4.6%) as well as "chasing another fish" (7.2%) due to their little observations. With a very low frequency of occurrence following behaviors like "spitting feed", "snapping feed from surface", "grazing the surface" and "scraping algae" are atypical. The cause that only a few pellets have been eaten from the surface can be attributed to their rapid fall. The relative high number of total activities shows a certain acceptance of the food.

Table 5.2: CA40, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	119	37.78	13.21	T	17.5
b	spitting feed/ algae	2	37.78	-5.82	AT	0.3
d	feed is too big trying to snap	12	37.78	-4.19	AT	1.8
e	snapping small particles	0	37.78	-6.15	AT	0.0
f	snapping feed from bottom	197	37.78	25.91	T	29.0
g	chewing	99	37.78	9.96	T	14.6
i	snapping feed from surface	1	37.78	-5.98	AT	0.1
l	collecting particles from the bottom	31	37.78	-1.10	n.s.	4.6
m	spitting particles through gills	146	37.78	17.61	T	21.5
n	grazing the surface, filtering	0	37.78	-6.15	AT	0.0
o	losing the feed	3	37.78	-5.66	AT	0.4
p	snapping fish excrements	2	37.78	-5.82	AT	0.3
q	scraping algae of the wall	12	37.78	-4.19	AT	1.8
r	scraping algae from bottom	0	37.78	-6.15	AT	0.0
t	snapping lost feed again	1	37.78	-5.98	AT	0.1
u	turning away from feed	3	37.78	-5.66	AT	0.4
w	chasing another fish	49	37.78	1.83	n.s.	7.2
y	spitting crushed pellet	3	37.78	-5.66	AT	0.4
	total	680	680.00			100.0

Note: e = 680/18 = 37.78 (uniform distribution)
Global Test (for total distribution): χ^2 = 1643.4; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

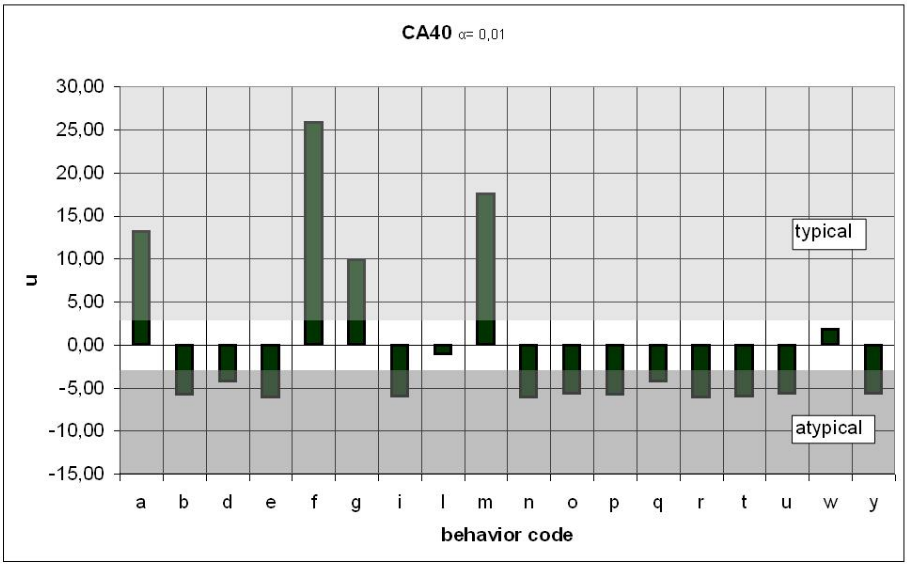

Figure 5.5: CA40, graphical presentation of the significance

5.2.3 CA50

For CA50 typical behaviors are “snapping feed from bottom” (11.5%), “chewing” (9.7%), “collecting particles from bottom” (19.3%), “spitting particles” (20.1%) and “filtering the surface” (8.8%) as it is presented in table 5.3 and figure 5.6. “Spitting particles” was the most observed habit (20.1%) followed by “collecting particles from bottom” (19.3%). “Snapping feed from water column” (4.8%) is not detectable as typical behavior any longer which can be explained as decreasing interest in the feed due to a higher share of Cassava leaves. Furthermore the pellets seem not to be as compact as the already mentioned cassava leaves based feed types, therefore moore loose particles remain floating on the surface, which are then grazed by the fish. The activity “scraping algae” (8.9%) was dedected with a higher frequency than it was accounted within the diet “CA40” but still is not a significant/ typical habit.

Table 5.3: CA50, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	34	39.06	-0.81	n.s.	4.8
b	spitting feed/ algae	21	39.06	-2.89	AT	3.0
d	feed is too big trying to snap	1	39.06	-6.09	AT	0.1
e	snapping small particles	0	39.06	-6.25	AT	0.0
f	snapping feed from bottom	81	39.06	6.71	T	11.5
g	chewing	68	39.06	4.63	T	9.7
i	snapping feed from surface	26	39.06	-2.09	n.s.	3.7
l	collecting particles from the bottom	136	39.06	15.51	T	19.3
m	spitting particles through gills	141	39.06	16.31	T	20.1
n	grazing the surface, filtering	62	39.06	3.67	T	8.8
o	losing the feed	1	39.06	-6.09	AT	0.1
p	snapping fish excrements	0	39.06	-6.25	AT	0.0
q	scraping algae of the wall	53	39.06	2.23	n.s.	7.5
r	scraping algae from bottom	10	39.06	-4.65	AT	1.4
t	snapping lost feed again	0	39.06	-6.25	AT	0.0
u	turning away from feed	5	39.06	-5.45	AT	0.7
w	chasing another fish	55	39.06	2.55	n.s.	7.8
y	spitting crushed pellet	9	39.06	-4.81	AT	1.3
	total	703	703.00			100.0

Note: e = 703/18 = 39.06 (uniform distribution)
Global Test (for total distribution): χ^2 = 877.3; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u > $u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u < $u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

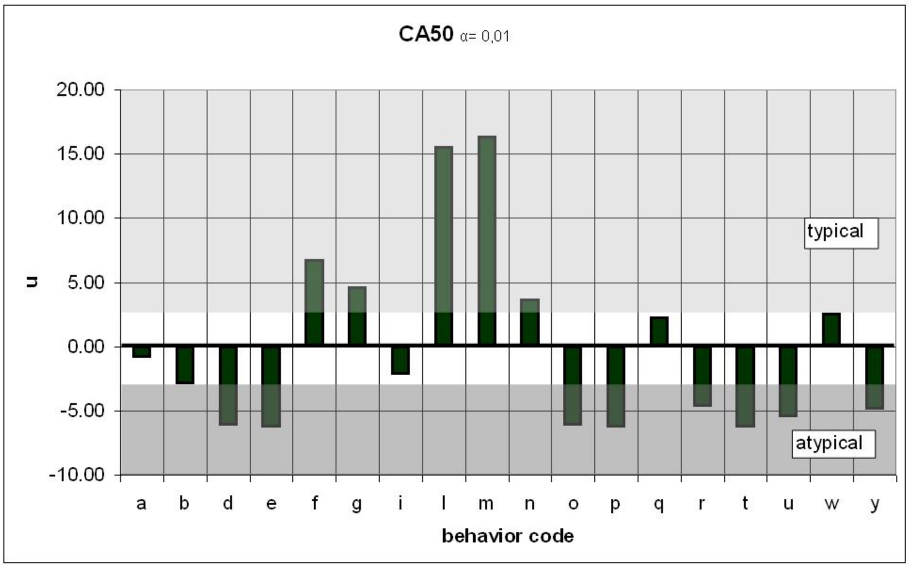

Figure 5.6: CA50, graphical presentation of the significance

5.2.4 CA60

"Collecting particles from bottom" (12.1%), "scraping algae of the wall" (37.4%) and "chasing another fish" (25.7%) are typical behaviors for the diet "CA60" (see table 5.4 and figure 5.7). Most often, with a percentage of 37.4%, it was observed that the fish were scraping algae of the tank. This can be understood as a preference for the algae instead of the pellets. In almost 25.7% of the observed cases "chasing another fish" was performed, which means that the fish rather defended their spot then intaking feed. At the beginning, the fish tasted the pellets from the bottom (3.9%) and later have passed to collect only particles from the bottom (12.1%) and for scraping algae. "Snapping feed from water column" (1%) and "snapping feed from surface" (1%) for instance were observed only very rarely and are therefore atypical. Clearly visible is the decrease of specific activities to a total of only 206 because of the very small number of feed intake observations, which indicates a declining interest in this diet. "Snapping feed from bottom" (3.9%) was accounted more often but it is still not a significant behavior for this feed. The small number of "chewing" and "spitting feed" (in contrast to the aforementioned cases) is due to the fact that the food was mostly just tried a few times and then ignored more or less.

Table 5.4: CA60, mathematical presentation of the significance

code	behavior	o	e	$u = (b-e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	2	11.44	-2.79	AT	1.0
b	spitting feed/ algae	1	11.44	-3.09	AT	0.5
d	feed is too big trying to snap	0	11.44	-3.38	AT	0.0
e	snapping small particles	0	11.44	-3.38	AT	0.0
f	snapping feed from bottom	8	11.44	-1.02	n.s.	3.9
g	chewing	6	11.44	-1.61	n.s.	2.9
i	snapping feed from surface	2	11.44	-2.79	AT	1.0
l	collecting particles from the bottom	25	11.44	4.01	T	12.1
m	spitting particles through gills	10	11.44	-0.43	n.s.	4.9
n	grazing the surface, filtering	0	11.44	-3.38	AT	0.0
o	losing the feed	0	11.44	-3.38	AT	0.0
p	snapping fish excrements	1	11.44	-3.09	AT	0.5
q	scraping algae of the wall	77	11.44	19.38	T	37.4
r	scraping algae from bottom	20	11.44	2.53	n.s.	9.7
t	snapping lost feed again	0	11.44	-3.38	AT	0.0
u	turning away from feed	0	11.44	-3.38	AT	0.0
w	chasing another fish	53	11.44	12.28	T	25.7
y	spitting crushed pellet	1	11.44	-3.09	AT	0.5
	total	206	206.00			100.0

Note: e = 206/18 = 11.44 (uniform distribution)
Global Test (for total distribution): χ^2 = 665.5; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u > $u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u < $u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

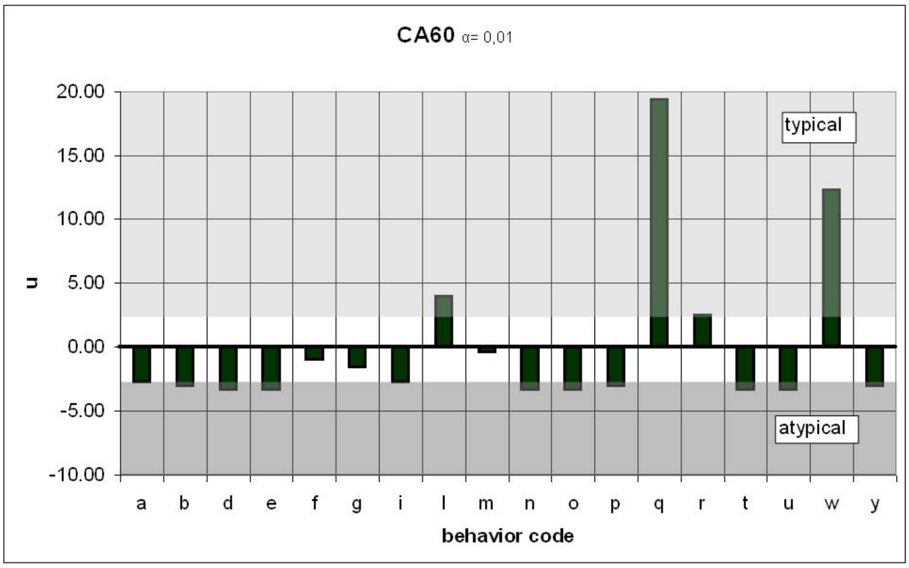

Figure 5.7: CA60, graphical presentation of the significance

5.2.5 MA30

Like it is listed in table 5.5 and figure 5.8 the most observed typical behavior with 25.9% of the observed cases was "collecting particles from the bottom" and "snapping feed from bottom" (13.7%). After snapping the feed, very often the pellets were spat out immediately (16.2%) which indicates the dislike of the diet as well as the behavior "chasing another fish" with a observed percentage of 14.3. Rarely the habits "snapping feed from water column" (5.6%) and "snapping feed from surface" (1.6%) were observed. This suggests that the fish were not really interested in the feed after it was thrown into the water. A total number of 321 activities is showing a certain interest in the new feed but after trying it is more or less refused. The higher counts of "collecting particles from the bottom" could be the result of collecting particularly particles of breweries waste.

Table 5.5: MA30, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	18	17.83	0.04	n.s.	5.6
b	spitting feed/ algae	52	17.83	8.09	T	16.2
d	feed is too big trying to snap	3	17.83	-3.51	AT	0.9
e	snapping small particles	8	17.83	-2.33	n.s.	2.5
f	snapping feed from bottom	44	17.83	6.20	T	13.7
g	chewing	4	17.83	-3.28	AT	1.2
i	snapping feed from surface	5	17.83	-3.04	AT	1.6
l	collecting particles from the bottom	83	17.83	15.43	T	25.9
m	spitting particles through gills	18	17.83	0.04	n.s.	5.6
n	grazing the surface, filtering	0	17.83	-4.22	AT	0.0
o	losing the feed	0	17.83	-4.22	AT	0.0
p	snapping fish excrements	1	17.83	-3.99	AT	0.3
q	scraping algae of the wall	13	17.83	-1.14	n.s.	4.0
r	scraping algae from bottom	22	17.83	0.99	n.s.	6.9
t	snapping lost feed again	0	17.83	-4.22	AT	0.0
u	turning away from feed	0	17.83	-4.22	AT	0.0
w	chasing another fish	46	17.83	6.67	T	14.3
y	spitting crushed pellet	4	17.83	-3.28	AT	1.2
	total	321	321.00			100.0

Note: e = 321/18 = 17.83 (uniform distribution)
Global Test (for total distribution): χ^2 = 524.4; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

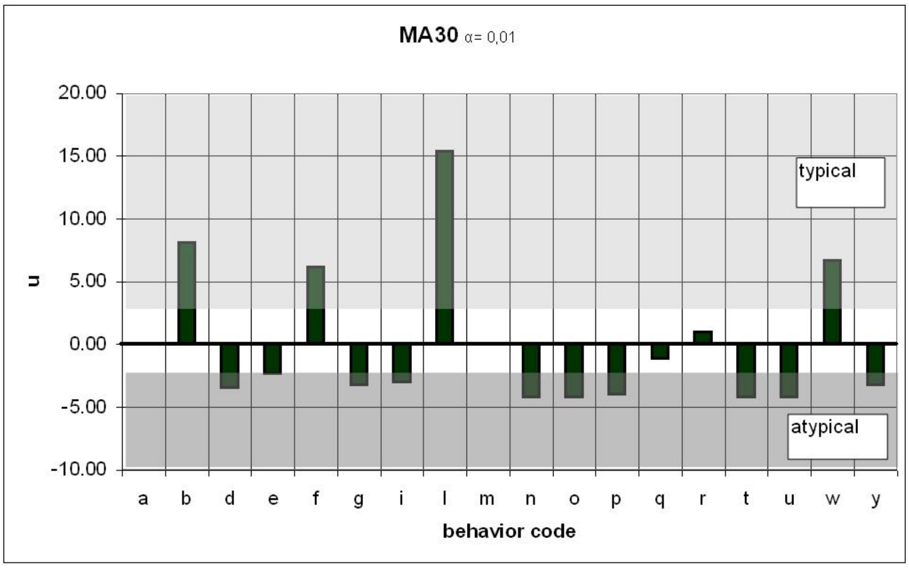

Figure 5.8: MA30, graphical presentation of the significance

5.2.6 MAV

For the diet MAV, typical behaviors are "collecting particles from bottom" (23.2%), "scraping algae of the wall" (18.6%) and "chasing another fish" (20.1%). "Snapping feed from bottom" and "spitting particles" were both observed with a percentage of 9.8 (see table 5.6 and figure 5.9). Because of the lack of interest for "snapping feed from the water column" (4.6%), "snapping feed from the surface" (0.5%) and the high share of "algae intake", it can be concluded that the diet is not accepted very well. Also the number of all observed activities (194) is relatively low compared to other diets which also indicates a dislike and includes furthermore a relatively high share of observations of "chasing another fish". With a lower accounted frequency "snapping feed from bottom (9.8%) and "chewing" (6.7%) followed by "spitting particles" (9.8%) are noted as not significant. Since "collecting particles from the bottom" was observed much more frequently than the eating of whole pellets (code "f"), it can be assumed that the spent grains were filtered out and eaten. The percentage of spent grains in this formulation is quite high since this is a volumetric mixture with equal parts of Mexican sunflower and breweries waste. The high noticed percentage for chasing after each other can also be the result of hunger and aggressions.

Table 5.6: MAV, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	9	10.78	-0.54	n.s.	4.6
b	spitting feed/ algae	5	10.78	-1.76	n.s.	2.6
d	feed is too big trying to snap	0	10.78	-3.28	AT	0.0
e	snapping small particles	2	10.78	-2.67	AT	1.0
f	snapping feed from bottom	19	10.78	2.50	n.s.	9.8
g	chewing	13	10.78	0.68	n.s.	6.7
i	snapping feed from surface	1	10.78	-2.98	AT	0.5
l	collecting particles from the bottom	45	10.78	10.42	T	23.2
m	spitting particles through gills	19	10.78	2.50	n.s.	9.8
n	grazing the surface, filtering	0	10.78	-3.28	AT	0.0
o	losing the feed	1	10.78	-2.98	AT	0.5
p	snapping fish excrements	0	10.78	-3.28	AT	0.0
q	scraping algae of the wall	36	10.78	7.68	T	18.6
r	scraping algae from bottom	2	10.78	-2.67	AT	1.0
t	snapping lost feed again	1	10.78	-2.98	AT	0.5
u	turning away from feed	0	10.78	-3.28	AT	0.0
w	chasing another fish	39	10.78	8.60	T	20.1
y	spitting crushed pellet	2	10.78	-2.67	AT	1.0
	total	194	194.00			100.0

Note: e = 194/18 = 10.78 (uniform distribution)
Global Test (for total distribution): χ^2 = 349.2; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

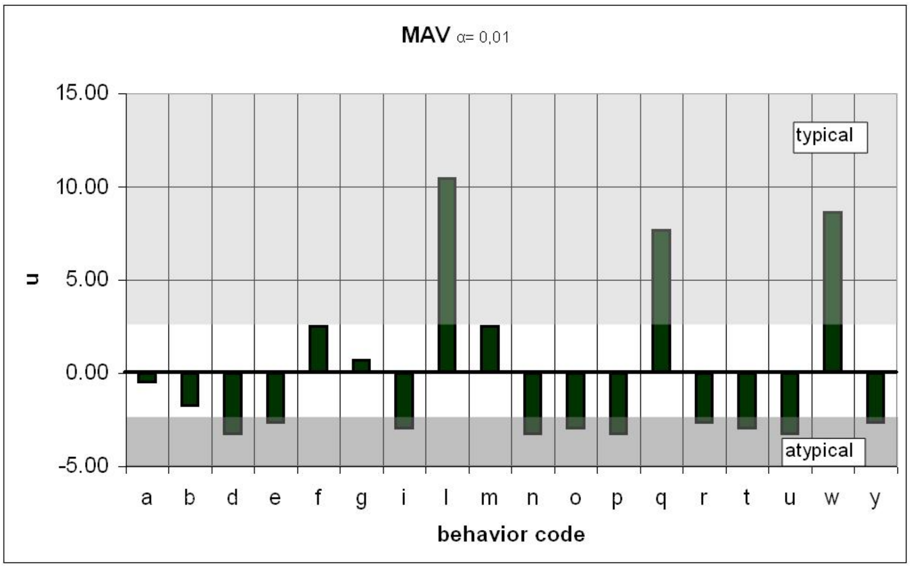

Figure 5.9: MAV, graphical presentation of the significance

5.2.7 MG30

"Snapping feed from bottom" (17.2%), "collecting particles from bottom" (37.9%) and "chasing another fish" (11.2%) are typical for this diet as it is shown in table 5.7 and figure 5.10. Like for the feed "MA30", the habit "spitting feed" was observed in many cases (9.5%) which indicates that the feed is rejected by the fish. The scraping of algae from the bottom and the walls of the tanks (code "q" and "r") with an occurence of 7.7% in total are also showing a lack of interest in the added feed. Like mentioned above, it was only rarely observable (4.1%) that the fish snapped feed from the water column (code "a") or "snapped feed from the surface" (1.8%). They were in no hurry to eat the feed immediately, on the contrary, the pellets were first falling down to the bottom and after a certain time tried there, also due to the rapid sinking. Mostly they were spat immediately, only smaller particles were collected. Also the number of all observed activities (169) is relatively low, like it is for the other mixtures with Mexican sunflower leaves, compared to other diets which also indicates a dislike.

Table 5.7: MG30, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	7	9.39	-0.78	n.s.	4.1
b	spitting feed/ algae	16	9.39	2.16	n.s.	9.5
d	feed is too big trying to snap	0	9.39	-3.06	AT	0.0
e	snapping small particles	1	9.39	-2.74	AT	0.6
f	snapping feed from bottom	29	9.39	6.40	T	17.2
g	chewing	1	9.39	-2.74	AT	0.6
i	snapping feed from surface	3	9.39	-2.09	n.s.	1.8
l	collecting particles from the bottom	64	9.39	17.82	T	37.9
m	spitting particles through gills	13	9.39	1.18	n.s.	7.7
n	grazing the surface, filtering	0	9.39	-3.06	AT	0.0
o	losing the feed	0	9.39	-3.06	AT	0.0
p	snapping fish excrements	0	9.39	-3.06	AT	0.0
q	scraping algae of the wall	8	9.39	-0.45	n.s.	4.7
r	scraping algae from bottom	5	9.39	-1.43	n.s.	3.0
t	snapping lost feed again	0	9.39	-3.06	AT	0.0
u	turning away from feed	2	9.39	-2.41	n.s.	1.2
w	chasing another fish	19	9.39	3.14	T	11.2
y	spitting crushed pellet	1	9.39	-2.74	AT	0.6
	total	169	169.00			100.0

Note: e = 169/18 = 9.39 (uniform distribution)
Global Test (for total distribution): χ^2 = 457.0; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

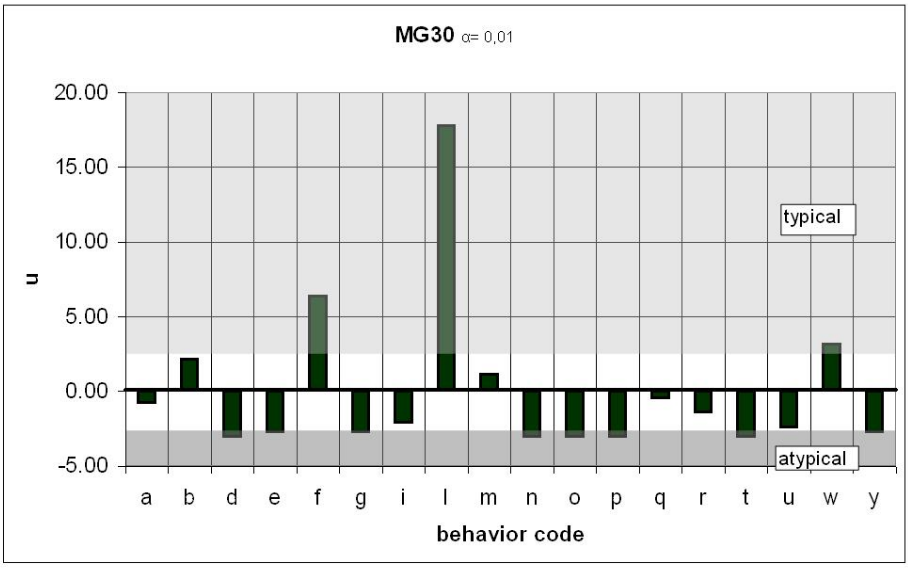

Figure 5.10: MG30, graphical presentation of the significance

5.2.8 SA30

The typical feeding sequence for SA30 starts with "snapping feed from the bottom" which is performed with 29.8% of all activities, followed by a longer period of "chewing" with 18.4% and then "spitting particles through gills" (22.6%). Besides the fish were "snapping feed from the water column" (2.2%) and "snapping feed from the surface" (2.5%) in low frequency. These actions are accounted as atypical because of the rare incidence. Scraping algae in general was only observed in 3.6% of the cases, means it is a sign that the fish preferred the diet (see table 5.8 and figure 5.11). During all sequences of this diet, a total occurrence of 717 single activities, composed mainly of feeding activities, has been observed which can be interpreted as a relatively high interest in this feed. The habit of "chasing another fish" (5.4%) is not significant in this case."Collecting particles from the bottom" (4.9%) and "grazing the surface" (3.6%) were also accounted but only several times and are therefore not showing statistical significance.

Table 5.8: SA30, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	16	39.83	-3.78	AT	2.2
b	spitting feed/ algae	17	39.83	-3.62	AT	2.4
d	feed is too big trying to snap	3	39.83	-5.84	AT	0.4
e	snapping small particles	11	39.83	-4.57	AT	1.5
f	snapping feed from bottom	214	39.83	27.60	T	29.8
g	chewing	132	39.83	14.60	T	18.4
i	snapping feed from surface	18	39.83	-3.46	AT	2.5
l	collecting particles from the bottom	35	39.83	-0.77	n.s.	4.9
m	spitting particles through gills	162	39.83	19.36	T	22.6
n	grazing the surface, filtering	26	39.83	-2.19	n.s.	3.6
o	losing the feed	2	39.83	-5.99	AT	0.3
p	snapping fish excrements	3	39.83	-5.84	AT	0.4
q	scraping algae of the wall	19	39.83	-3.30	AT	2.6
r	scraping algae from bottom	7	39.83	-5.20	AT	1.0
t	snapping lost feed again	1	39.83	-6.15	AT	0.1
u	turning away from feed	0	39.83	-6.31	AT	0.0
w	chasing another fish	39	39.83	-0.13	n.s.	5.4
y	spitting crushed pellet	12	39.83	-4.41	AT	1.7
	total	717	717.00			100.0

Note: e = 717/18 = 39.83 (uniform distribution)
Global Test (for total distribution): χ^2 = 1654.2; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

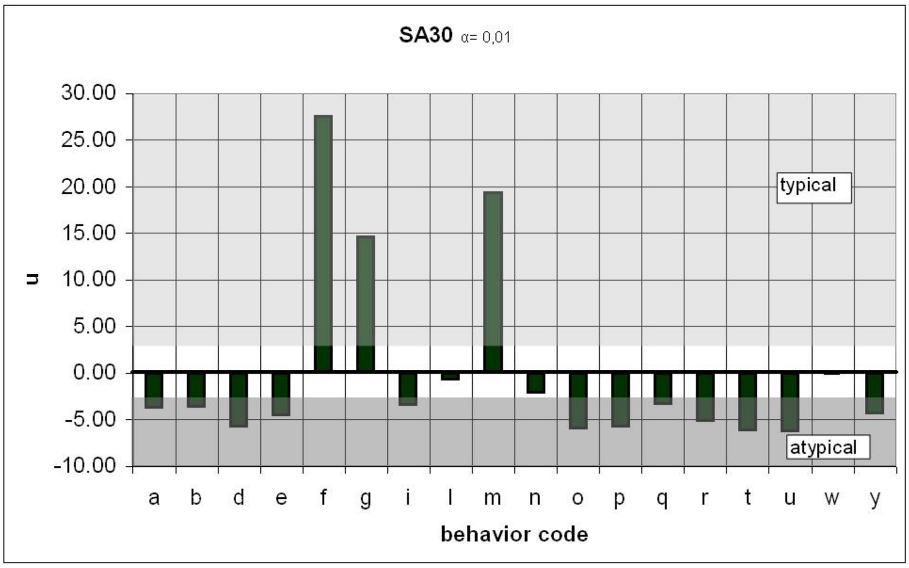

Figure 5.11: SA30, graphical presentation of the significance

5.2.9 SA40

The most observed habits for this diet were "scraping algae of the wall" with 24.8% of all performed actions, followed by "chasing another fish" with 24.4% (see table 5.9 and figure 5.12). These actions are accounted as typical because of their high occurence as well as "snapping feed from the bottom" (14.3%). Also "collecting particles from the bottom" was performed more frequently with 9% than all other activities as well as "spitting particles" with 7.9% and "snapping feed from water column" (1.9%) but without statistical significance. Atypical behaviors are "spitting feed" (0.8%) and "snapping feed from the surface" (0.8%). With totally 266 counted observations, the fish are showing a somewhat lower interest than it was within the feed SA30. The high percentage of chasing after each other can also be the result of hunger and aggressions and the dislike of this feedstuff.

Table 5.9: SA40, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	5	14.78	-2.54	n.s.	1.9
b	spitting feed/ algae	2	14.78	-3.32	AT	0.8
d	feed is too big trying to snap	7	14.78	-2.02	n.s.	2.6
e	snapping small particles	0	14.78	-3.84	AT	0.0
f	snapping feed from bottom	38	14.78	6.04	T	14.3
g	chewing	17	14.78	0.58	n.s.	6.4
i	snapping feed from surface	2	14.78	-3.32	AT	0.8
l	collecting particles from the bottom	24	14.78	2.40	n.s.	9.0
m	spitting particles through gills	21	14.78	1.62	n.s.	7.9
n	grazing the surface, filtering	0	14.78	-3.84	AT	0.0
o	losing the feed	0	14.78	-3.84	AT	0.0
p	snapping fish excrements	3	14.78	-3.06	AT	1.1
q	scraping algae of the wall	66	14.78	13.32	T	24.8
r	scraping algae from bottom	15	14.78	0.06	n.s.	5.6
t	snapping lost feed again	0	14.78	-3.84	AT	0.0
u	turning away from feed	1	14.78	-3.58	AT	0.4
w	chasing another fish	65	14.78	13.06	T	24.4
y	spitting crushed pellet	0	14.78	-3.84	AT	0.0
	total	266	266.00			100.0

Note: e = 266/18 = 14.78 (uniform distribution)
Global Test (for total distribution): $\chi^2 = 522.2$; df = 18-1 = 17; $\chi^2(0{,}01;17) = 33.41$; $\chi^2 > \chi^2(0{,}01;17) \rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when $+u > u_\alpha = u_{0,01} = 2{,}56$ then is typical (T); when $-u < u_\alpha = u_{0,01} = -2{,}56$ then is atypical (AT)

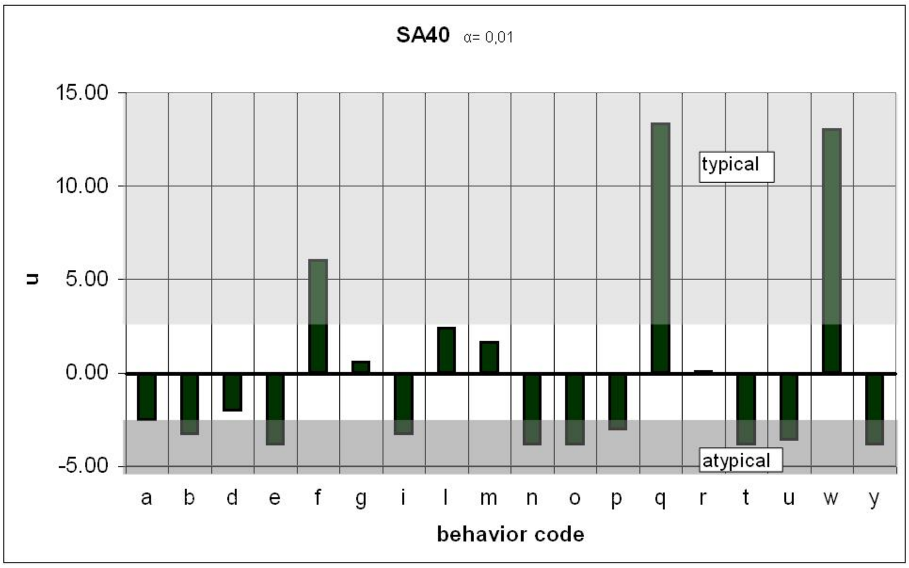

Figure 5.12: SA40, graphical presentation of the significance

5.2.10 SA50

"Grazing the surface" (13.9%), "spitting particles" (15.9%), "chewing" (13.4%), "chasing another fish" (10.6%) and "scragping algae" (16.8%) are typical behaviors for this diet like it is presented in table 5.10 and figure 5.13. Furthermore "snapping feed from the surface" was observed more frequently with 7.5% of the observations, like "snapping feed from water column" (5.7%), "snapping feed from bottom" (3.7%) and "spitting feed (3.9%) but due to their not so high occurrence they are classified as not significant behaviors. "Collecting particles from bottom" (2.7%) and "snapping small particles" are examples for atypical behaviors and therefore performed only rarely. The frequent counts of "chasing" and "algae- intake" can be interpreted as lower interest in the feedstuff.

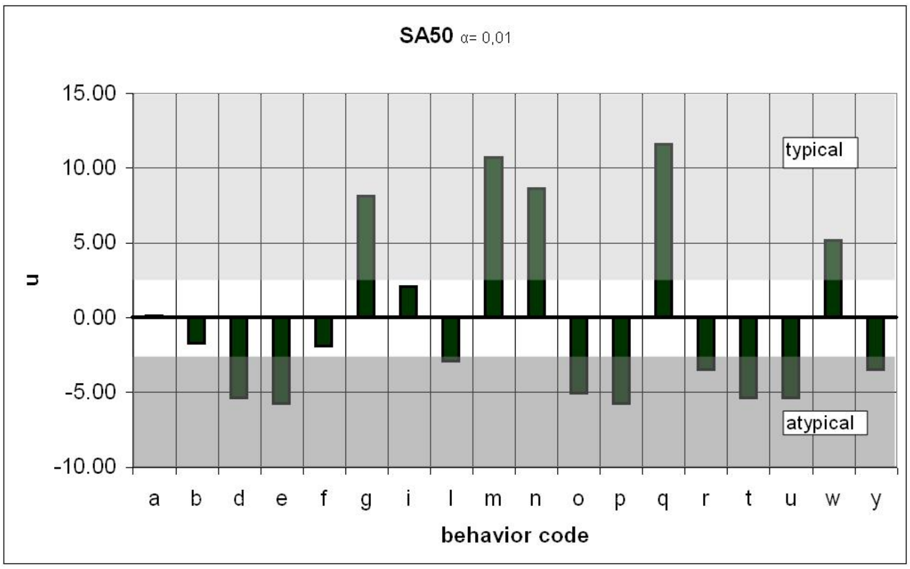

Figure 5.13: SA50, graphical presentation of the significance

Table 5.10: SA50, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	34	33.17	0.14	n.s.	5.7
b	spitting feed/ algae	23	33.17	-1.77	n.s.	3.9
d	feed is too big trying to snap	2	33.17	-5.41	AT	0.3
e	snapping small particles	0	33.17	-5.76	AT	0.0
f	snapping feed from bottom	22	33.17	-1.94	n.s.	3.7
g	chewing	80	33.17	8.13	T	13.4
i	snapping feed from surface	45	33.17	2.05	n.s.	7.5
l	collecting particles from the bottom	16	33.17	-2.98	AT	2.7
m	spitting particles through gills	95	33.17	10.74	T	15.9
n	grazing the surface, filtering	83	33.17	8.65	T	13.9
o	losing the feed	4	33.17	-5.06	AT	0.7
p	snapping fish excrements	0	33.17	-5.76	AT	0.0
q	scraping algae of the wall	100	33.17	11.60	T	16.8
r	scraping algae from bottom	13	33.17	-3.50	AT	2.2
t	snapping lost feed again	2	33.17	-5.41	AT	0.3
u	turning away from feed	2	33.17	-5.41	AT	0.3
w	chasing another fish	63	33.17	5.18	T	10.6
y	spitting crushed pellet	13	33.17	-3.50	AT	2.2
	total	597	597.00			100.0

Note: e = 597/18 = 33.17 (uniform distribution)
Global Test (for total distribution): χ^2 = 642.2; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u > $u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u < $u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

5.2.11 SA70

For the diet SA70 “chasing another fish” (27.1%), “scraping algae of the wall” (16.5%), “snapping feed from bottom” (15.4%) and “collecting particles from the bottom” (14.9%) are accounted very frequently (see table 5.11 and figure 5.14). The high observation of “chasing” and “algae-intake” can be seen as lower interest in the feedstuff and can also be the result of hunger and aggressions. No significance are showing activities like “snapping feed from water column” (5.3%), “chewing” (4.8%) and “spitting particles through gills” (5.3%). Atypical behaviors are for example “grazing the surface” with any single observation and “snapping feed from the surface” (0.5%). The cause for this may be on the one hand the specific disinterest of the fish or also the rapid sinking of the pellets on the other hand. It has to be noted that this formulation includes only a relatively small proportion of breweries waste. The pattern behavior for “chewing” followed by “spitting particles through gills” is not typical in this case like it was in the diets presented before.

Table 5.11: SA70, mathematical presentation of the significance

code	behavior	o	e	$u = (b-e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	10	10.44	-0.14	n.s.	5.3
b	spitting feed/ algae	2	10.44	-2.61	AT	1.1
d	feed is too big trying to snap	1	10.44	-2.92	AT	0.5
e	snapping small particles	0	10.44	-3.23	AT	0.0
f	snapping feed from bottom	29	10.44	5.74	T	15.4
g	chewing	9	10.44	-0.45	n.s.	4.8
i	snapping feed from surface	1	10.44	-2.92	AT	0.5
l	collecting particles from the bottom	28	10.44	5.43	T	14.9
m	spitting particles through gills	10	10.44	-0.14	n.s.	5.3
n	grazing the surface, filtering	0	10.44	-3.23	AT	0.0
o	losing the feed	3	10.44	-2.30	n.s.	1.6
p	snapping fish excrements	3	10.44	-2.30	n.s.	1.6
q	scraping algae of the wall	31	10.44	6.36	T	16.5
r	scraping algae from bottom	4	10.44	-1.99	n.s.	2.1
t	snapping lost feed again	1	10.44	-2.92	AT	0.5
u	turning away from feed	0	10.44	-3.23	AT	0.0
w	chasing another fish	51	10.44	12.55	T	27.1
y	spitting crushed pellet	5	10.44	-1.68	n.s.	2.7
	total	188	188.00			100.0

Note: e = 188/18 = 10.44 (uniform distribution)
Global Test (for total distribution): χ^2 = 341.9; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u > $u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u < $u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

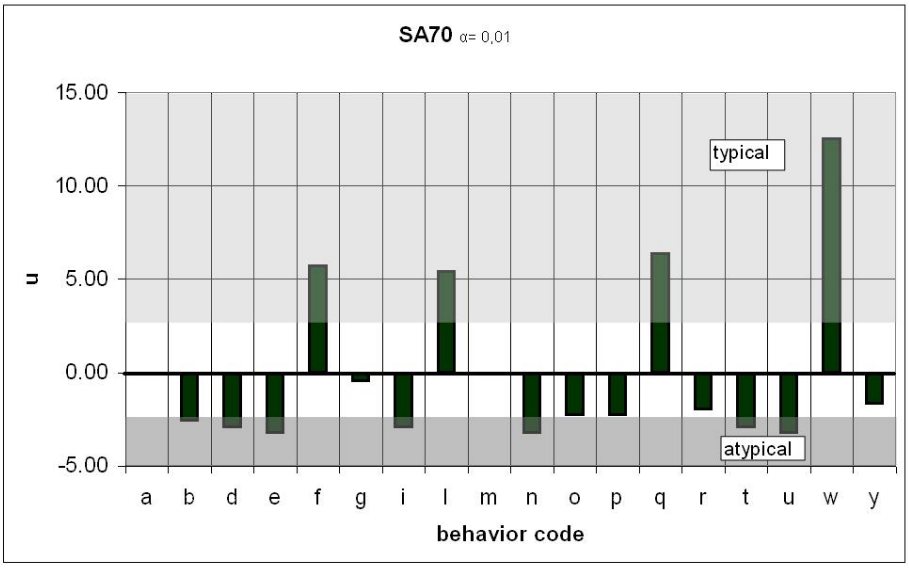

Figure 5.14: SA70, graphical presentation of the significance

5.2.12 SAV

A typical behavior pattern can be detected within this feed which is composed as follows "snapping feed from bottom" (26.5%), thereafter a longer time of "chewing" (15.4%) and finally "spitting particles through gills" (21%). Furthermore "scraping algae of the wall" is tyical for this diet and was observed in 14.0% of all performed actions (see table 5.12 and figure 5.15). SAV is the diet with the highest share of breweries waste. Altogether 486 single activities have been detected. "Snapping feed from water column" (1.2%), "spitting feed" (1.6%), "snapping feed from surface" (1.0%) and "collecting particles from bottom" (2.1%) are among other activities accounted as atypical habits because of their rare occurrence. No significance is showing the habit "chasing another fish" (7.0%) which can be interpreted as a higher interest in this diet and therefore a better acceptance. The less accounted frequencies of "snapping feed from water column" (1.2%) and "snapping feed from surface" (1.0%) could be the result of the relatively fast descent rate of the pellets.

Table 5.12: SAV, mathematical presentation of the significance

code	behavior	o	e	$u = (b-e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	6	27.00	-4.04	AT	1.2
b	spitting feed/ algae	8	27.00	-3.66	AT	1.6
d	feed is too big trying to snap	4	27.00	-4.43	AT	0.8
e	snapping small particles	0	27.00	-5.20	AT	0.0
f	snapping feed from bottom	129	27.00	19.63	T	26.5
g	chewing	75	27.00	9.24	T	15.4
i	snapping feed from surface	5	27.00	-4.23	AT	1.0
l	collecting particles from the bottom	10	27.00	-3.27	AT	2.1
m	spitting particles through gills	102	27.00	14.43	T	21.0
n	grazing the surface, filtering	37	27.00	1.92	n.s.	7.6
o	losing the feed	0	27.00	-5.20	AT	0.0
p	snapping fish excrements	0	27.00	-5.20	AT	0.0
q	scraping algae of the wall	68	27.00	7.89	T	14.0
r	scraping algae from bottom	7	27.00	-3.85	AT	1.4
t	snapping lost feed again	0	27.00	-5.20	AT	0.0
u	turning away from feed	1	27.00	-5.00	AT	0.2
w	chasing another fish	34	27.00	1.35	n.s.	7.0
y	spitting crushed pellet	0	27.00	-5.20	AT	0.0
	total	486	486.00			100.0

Note: e = 486/18 = 27.00 (uniform distribution)
Global Test (for total distribution): $\chi^2 = 999.6$; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01} =$ 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01} =$ -2,56 then is atypical (AT)

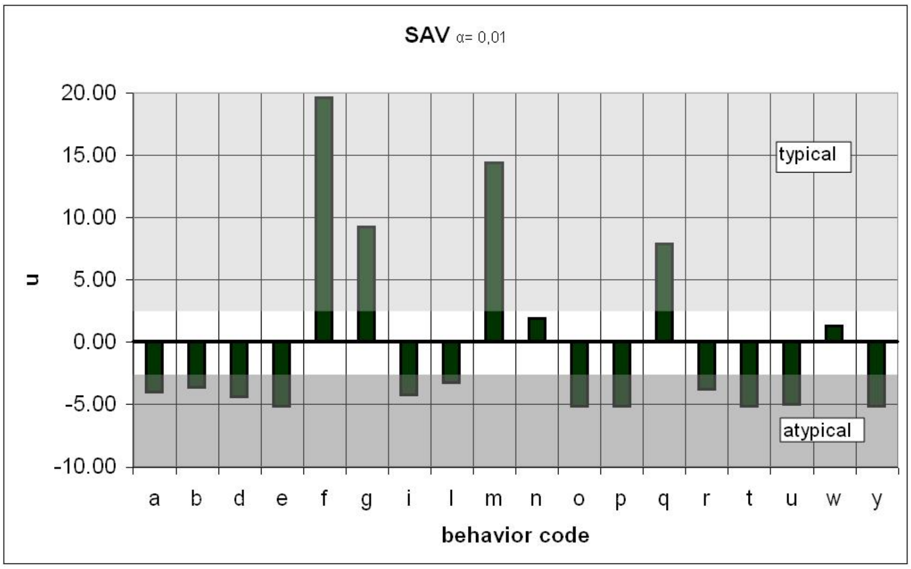

Figure 5.15: SAV, graphical presentation of the significance

5.2.13 SG40

In this diet with a share of 40% of Sweet potato leaves, typical feeding behaviors are "filtering the surface" (25.5%), "snapping feed from bottom" (13.8%), "collecting particles from bottom" (13.5%), "spitting particles through gills" (19.9%) and "scraping algae of the wall" (8.2%) (see table 5.13 and figure 5.16). By contrast, "snapping feed from water column" (0.4%), "spitting feed" (3.0%) and "spitting crushed pellets" are observed as atypcial. "Chasing another fish" (4.5%) and "chewing" (5.8%) are noted as not significant acitvities. The total number of observed activities is relatively high, at 674, particularly due to the really high number of "grazing the surface".

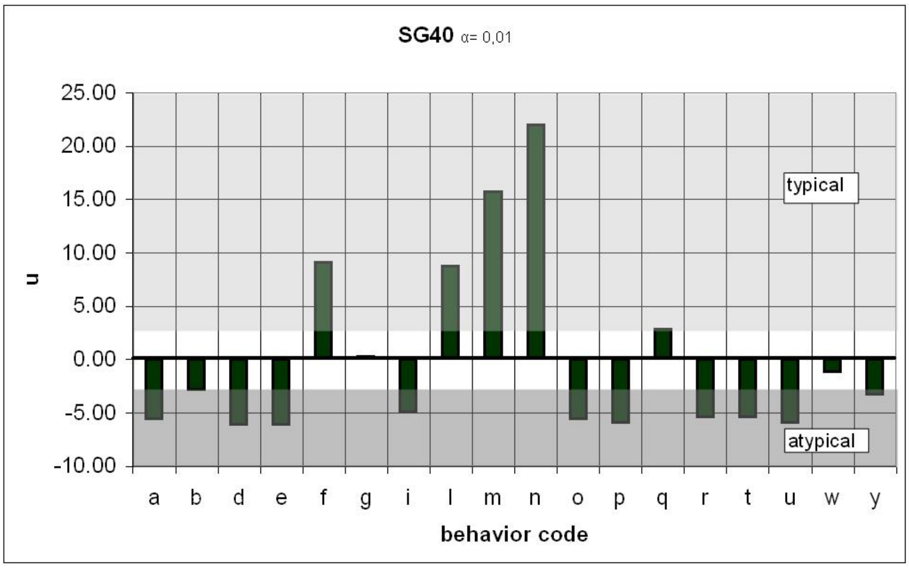

Figure 5.16: SG40, graphical presentation of the significance

Table 5.13: SG40, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	3	37.44	-5.63	AT	0.4
b	spitting feed/ algae	20	37.44	-2.85	AT	3.0
d	feed is too big trying to snap	0	37.44	-6.12	AT	0.0
e	snapping small particles	0	37.44	-6.12	AT	0.0
f	snapping feed from bottom	93	37.44	9.08	T	13.8
g	chewing	39	37.44	0.25	n.s.	5.8
i	snapping feed from surface	7	37.44	-4.98	AT	1.0
l	collecting particles from the bottom	91	37.44	8.75	T	13.5
m	spitting particles through gills	134	37.44	15.78	T	19.9
n	grazing the surface, filtering	172	37.44	21.99	T	25.5
o	losing the feed	3	37.44	-5.63	AT	0.4
p	snapping fish excrements	1	37.44	-5.96	AT	0.1
q	scraping algae of the wall	55	37.44	2.87	T	8.2
r	scraping algae from bottom	4	37.44	-5.47	AT	0.6
t	snapping lost feed again	4	37.44	-5.47	AT	0.6
u	turning away from feed	1	37.44	-5.96	AT	0.1
w	chasing another fish	30	37.44	-1.22	n.s.	4.5
y	spitting crushed pellet	17	37.44	-3.34	AT	2.5
	total	674	674.00			100.0

Note: e = 674/18 = 37.44 (uniform distribution)
Global Test (for total distribution): χ^2 = 1214.3; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

5.2.14 SAG

"Sagana" is the usually fed diet on the fish farm and very well accepted by the fish, as evidenced by the results. From the analysis it is known, that "snapping feed from water column" is the most performed activity with 42.8% when it is fed to the fish. "Snapping feed from the surface" (7.8%) and "snapping feed from bottom" (8.2%) are also very frequent activities for this feed. The reason why most of the pellets were eaten from the water column is caused by the reduced sinking rate and that most of the feedstuff was already eaten by the fish before it even reached the bottom of the tank (see table 5.14 and figure 5.17). "Chasing another fish" was also observed several times (7.9%) and can be categorized as typical because of the scramble for feed. Because of the fact that "scraping algae" was observed only very rarely (2.5%) it can be interpreted as an attractive sign of the diet "Sagana". The habits "spitting feed", "snapping small particles", "chewing", "collecting particles from bottom", "grazing the surface" and "snapping lost feed" could be observed, but only with low frequencies in comparison to "snapping feed from water column" and are therefore regarded as atypical. Not significant are the activities "losing the feed" (6%), "snapping feed from surface" (7,8%), "snapping lost feed again" (3.3%) and "spitting particles through gills" (4.2%) for this diet. "Sagana" was tested in two runs, resulting in an average of 361 single activities. The relatively low number is following from the fact that immediately after throwing in the feed the fish started to eat within a very short time and filled

their mouth with pellets. Therefore they needed the rest of the time for chewing and defending lost particles against other fish. This chewing can even last for a few minutes.
By the process of chewing, tilapia have the habit of spitting out smaller particles and snapping the biggest ones again. Sometimes it was not possible for them to keep all pellets in their mouth during chewing because they took too much of the feed and the particles were too big, so they had to spit it out again but snapped most of the particles once more.

Table 5.14: SG40, mathematical presentation of the significance

code	behavior	o	e	$u = (b-e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	309	40.11	42.46	T	42.8
b	spitting feed/ algae	17	40.11	-3.65	AT	2.4
d	feed is too big trying to snap	17	40.11	-3.65	AT	2.4
e	snapping small particles	22	40.11	-2.86	AT	3.0
f	snapping feed from bottom	59	40.11	2.98	T	8.2
g	chewing	18	40.11	-3.49	AT	2.5
i	snapping feed from surface	56	40.11	2.51	n.s.	7.8
l	collecting particles from the bottom	9	40.11	-4.91	AT	1.2
m	spitting particles through gills	30	40.11	-1.60	n.s.	4.2
n	grazing the surface, filtering	2	40.11	-6.02	AT	0.3
o	losing the feed	43	40.11	0.46	n.s.	6.0
p	snapping fish excrements	5	40.11	-5.54	AT	0.7
q	scraping algae of the wall	18	40.11	-3.49	AT	2.5
r	scraping algae from bottom	0	40.11	-6.33	AT	0.0
t	snapping lost feed again	24	40.11	-2.54	n.s.	3.3
u	turning away from feed	7	40.11	-5.23	AT	1.0
w	chasing another fish	57	40.11	2.67	T	7.9
y	spitting crushed pellet	29	40.11	-1.75	n.s.	4.0
	total	722	722.00			100.0

Note: e = 722/18 = 40.11 (uniform distribution)
Global Test (for total distribution): χ^2 = 2054.8; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

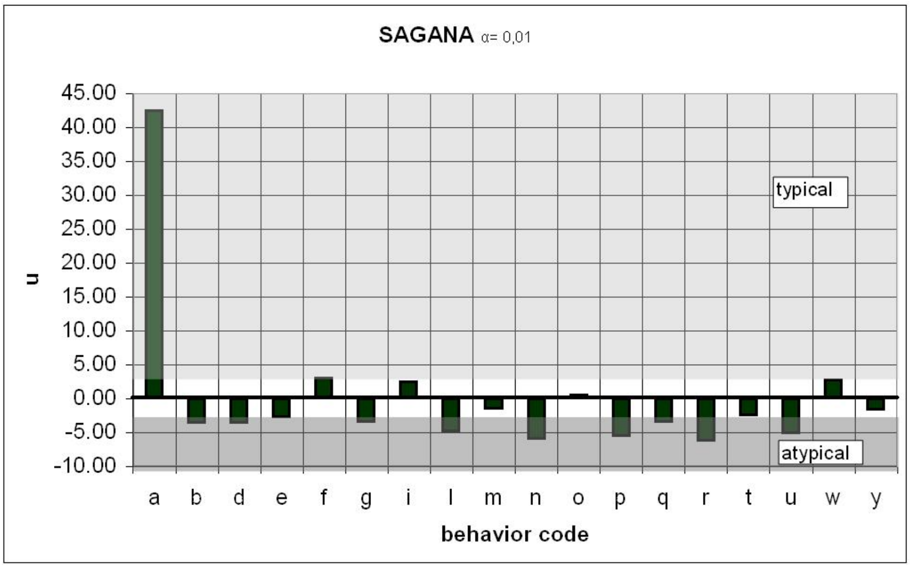

Figure 5.17: SAG, graphical presentation of the significance

5.2.15 CAS

"CAS" describes an average value of all four tested Cassava leaves based feeds. Overall one can say that typical behaviors for all mixtures are "snapping feed from water column" (9.6%), "snapping feed from bottom" (22.4%), "chewing" (13.7%), "collecting particles from bottom" (9.5%), "spitting particles through gills" (19.2%), "scraping algae of the walls" (7.7%) and "chasing another fish" (8.2%) (see table 5.15 and figure 5.18). As typical behavior pattern feed-intake followed by a certain time of chewing and afterwards spitting out small particles can be described. The preferred intake points of the fodder from the ground indicates that the feed falls relatively fast to the ground. Furthermore it could also be a sign for a lower interest and because of that it is not consumed immediately after the insert.

Table 5.15: CAS, mathematical presentation of the significance

code	behavior	o	e	$u = (b-e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	226	131.39	8.25	T	9.6
b	spitting feed/ algae	31	131.39	-8.76	AT	1.3
d	feed is too big trying to snap	17	131.39	-9.98	AT	0.7
e	snapping small particles	0	131.39	-11.46	AT	0.0
f	snapping feed from bottom	530	131.39	34.78	T	22.4
g	chewing	323	131.39	16.72	T	13.7
i	snapping feed from surface	29	131.39	-8.93	AT	1.2
l	collecting particles from the bottom	224	131.39	8.08	T	9.5
m	spitting particles through gills	454	131.39	28.14	T	19.2
n	grazing the surface, filtering	62	131.39	-6.05	AT	2.6
o	losing the feed	14	131.39	-10.24	AT	0.6
p	snapping fish excrements	4	131.39	-11.11	AT	0.2
q	scraping algae of the wall	181	131.39	4.33	T	7.7
r	scraping algae from bottom	47	131.39	-7.36	AT	2.0
t	snapping lost feed again	3	131.39	-11.20	AT	0.1
u	turning away from feed	11	131.39	-10.50	AT	0.5
w	chasing another fish	193	131.39	5.38	T	8.2
y	spitting crushed pellet	16	131.39	-10.07	AT	0.7
	total	2365	2365.00			100.0

Note: e = 2365/18 = 131.39 (uniform distribution)
Global Test (for total distribution): χ^2 = 3505.7; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

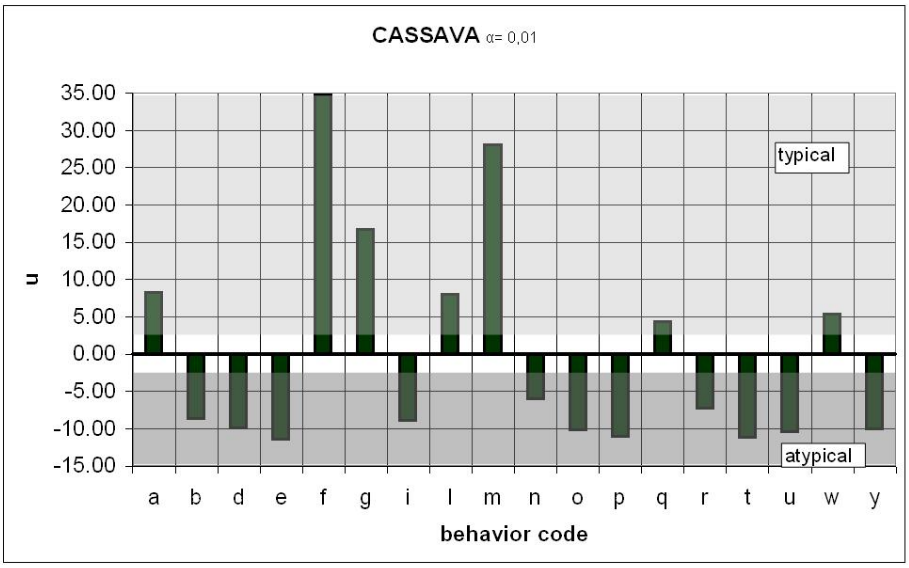

Figure 5.18: CAS, graphical presentation of the significance

5.2.16 MSF

Within the feed-group of Mexican sunflower leaves based feed (MSF), only three single mixtures were analyzed because of the obvious lack of interest. Typical behaviors are “collecting particles from the bottom” (28.1%), “snapping feed from bottom” (13.5%), “spitting feed” (10.7%), “scraping algae of the walls” (8.3%) and “chasing another fish” (15.2%). No significance are showing the habits “snapping feed from water column” (5.0%), “spitting particles” (7.3%) and “sraping algae from bottom” (4.2%) (see table 5.16 and figure 5.19). The atypical action of “chewing” (2.6%) demonstrates that in most cases, the feed was spit out immediatly after intake without chewing due to the bitterness of Mecixan sunflower. The relatively high number of observations of “chasing another fish” could be a sign for aggression and hunger.

Table 5.16: MSF, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	34	38.00	-0.65	n.s.	5.0
b	spitting feed/ algae	73	38.00	5.68	T	10.7
d	feed is too big trying to snap	3	38.00	-5.68	AT	0.4
e	snapping small particles	11	38.00	-4.38	AT	1.6
f	snapping feed from bottom	92	38.00	8.76	T	13.5
g	chewing	18	38.00	-3.24	AT	2.6
i	snapping feed from surface	9	38.00	-4.70	AT	1.3
l	collecting particles from the bottom	192	38.00	24.98	T	28.1
m	spitting particles through gills	50	38.00	1.95	n.s.	7.3
n	grazing the surface, filtering	0	38.00	-6.16	AT	0.0
o	losing the feed	1	38.00	-6.00	AT	0.1
p	snapping fish excrements	1	38.00	-6.00	AT	0.1
q	scraping algae of the wall	57	38.00	3.08	T	8.3
r	scraping algae from bottom	29	38.00	-1.46	n.s.	4.2
t	snapping lost feed again	1	38.00	-6.00	AT	0.1
u	turning away from feed	2	38.00	-5.84	AT	0.3
w	chasing another fish	104	38.00	10.71	T	15.2
y	spitting crushed pellet	7	38.00	-5.03	AT	1.0
	total	684	684.00			100.0

Note: e = 684/18 = 38.00 (uniform distribution)
Global Test (for total distribution): χ^2 = 1153.1; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2$(0,01;17) $\rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

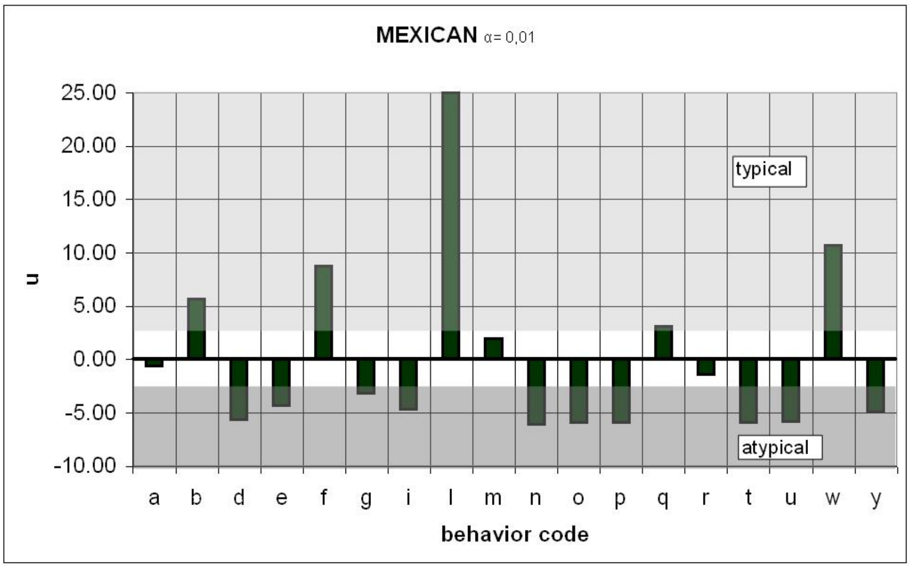

Figure 5.19: MSF, graphical presentation of the significance

5.2.17 SPL

Totally there were six different mixtures of Sweet potato leaves (SPL) based feed tested and analyzed in the observatory room. It is typical for this feed-group that the pellets were "snapped from the bottom" (17.9%) on that "particles were collecetd from the bottom" (7.0%), followed by "chewing" (12.0%) and "spitting out of particles" (17.9%). Furthermore habits like " grazing the surface, filtering" (10.9%) due to the retaining particles on the surface and "scraping algae of the wall" (11.6%) are typical observations as it is presented in table 5.17 and figure 5.20. A sign of lower acceptance of the diet is the occurrence of "chasing another fish" (9.6%) which is also analyzed as typical behavior. Due to the rapid descent rate of the pellets "snapping feed from surface" (2.7%) and "snapping feed from water column" (2.5%) are only observed with low frequency and are therefore classified as atypical.

Table 5.17: SPL, mathematical presentation of the significance

code	behavior	o	e	$u = (b - e)/\sqrt{e}$	T/ AT	o %
a	snapping feed from water column	74	162.67	-6.95	AT	2.5
b	spitting feed/ algae	72	162.67	-7.11	AT	2.5
d	feed is too big trying to snap	17	162.67	-11.42	AT	0.6
e	snapping small particles	11	162.67	-11.89	AT	0.4
f	snapping feed from bottom	525	162.67	28.41	T	17.9
g	chewing	352	162.67	14.84	T	12.0
i	snapping feed from surface	78	162.67	-6.64	AT	2.7
l	collecting particles from the bottom	204	162.67	3.24	T	7.0
m	spitting particles through gills	524	162.67	28.33	T	17.9
n	grazing the surface, filtering	318	162.67	12.18	T	10.9
o	losing the feed	12	162.67	-11.81	AT	0.4
p	snapping fish excrements	10	162.67	-11.97	AT	0.3
q	scraping algae of the wall	339	162.67	13.83	T	11.6
r	scraping algae from bottom	50	162.67	-8.83	AT	1.7
t	snapping lost feed again	8	162.67	-12.13	AT	0.3
u	turning away from feed	5	162.67	-12.36	AT	0.2
w	chasing another fish	282	162.67	9.36	T	9.6
y	spitting crushed pellet	47	162.67	-9.07	AT	1.6
	total	2928	2928.00			100.0

Note: e = 2928/18 = 162.67 (uniform distribution)
Global Test (for total distribution): χ^2 = 3425.4; df = 18-1 = 17; χ^2(0,01;17) =33.41; $\chi^2 > \chi^2(0,01;17) \rightarrow H_1$ (no uniform distribution)
Local Test (for every single cell): when +u $> u_\alpha = u_{0,01}$ = 2,56 then is typical (T); when -u $< u_\alpha = u_{0,01}$ = -2,56 then is atypical (AT)

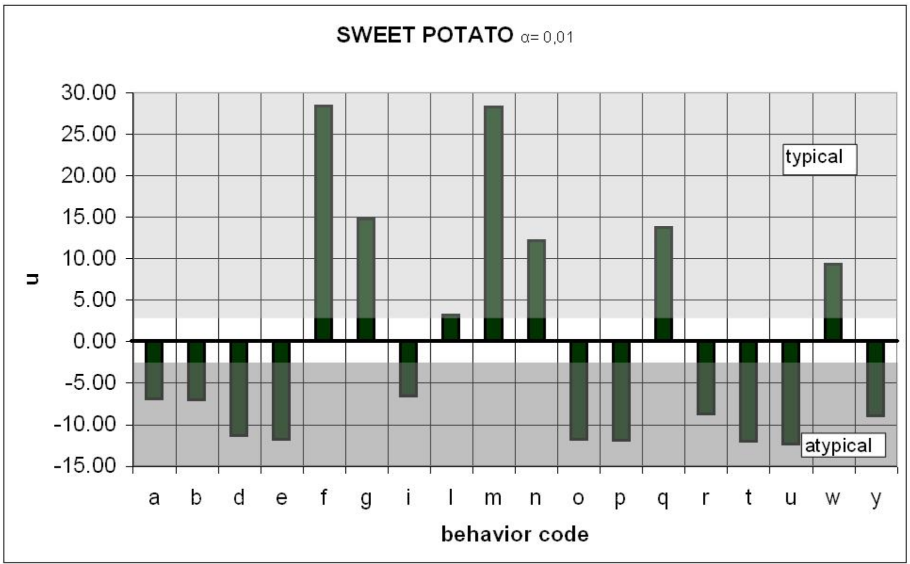

Figure 5.20: SPL, graphical presentation of the significance

5.2.18 Location of feed intake for the individual feed categories

Figure 5.21 is displaying the preferred places were feed was taken from (the bottom, water column or the surface of the observation tanks) and whether it is a typical or atypical behavior. The fields without hatching do not show any significance. The results are given in percent because of the different number of single analyzed diets of each feed-group.
For the underlying data (calculation) see Appendix table A.4.
For "Sagana", the reference diet, it is obvious that it was mostly taken from the water column during subsidence with an observed frequency of 71.0%. However some pellets were also caught from the surface (13.3%) immediately after they were dropped into the tank or rather taken later because of the fact that they remain for a longer time swimming. Some of the smaller particles and crushed pellets then were also snapped from the bottom of the aquarium (15.6%).
For the Cassava leaves based diets it is a typical behavior that it was taken from the bottom (70.4%) mainly due to the rapid descent rate. Pellets were also snapped from the water column (21.1%) but with no statistical significance. For the remaining 8.5% feed was taken from the surface, but with such a small number of observed frequencies that it can be classified as atypical.
Mexican sunflower leaves based feeds are sinking to the bottom very fast and disintegrate quickly. Therefore mostly small particles were taken from there (86.9%). Some pellets were also snapped from the water column (10.4%) and the surface (2.8%).
Also Sweet potato based pellets are disintegrating quickly but with the difference, that many particles are remaining on the water surface. Consequently the percentage of up-taking feed from the bottom is lower than within the two before mentioned feed-groups with an observed frequency of 60.8%. The atypical behavior of feed intake during sinking from the water column (6.2%) is showing a smaller interest in the feed because it is not eaten immediately after dropping it in.

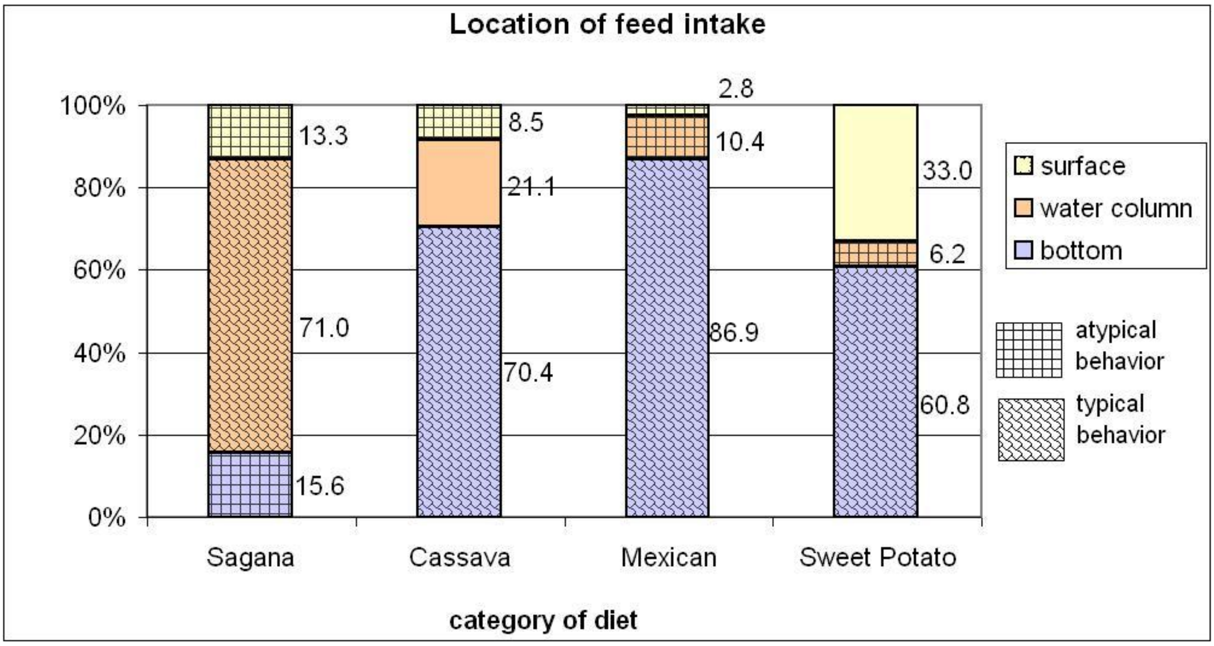

Figure 5.21: Location of feed intake

Chapter 6

Comparison, interpretation and discussion of results

In this chapter the individual mixtures within one feed category are compared to each other as well as the behavior patterns of the observed fish on the individual categories, based on the statistical analysis and the percentage distribution of the individual activities.
Furthermore figures of the average activities per feeding- unit and the feeding behavior concerning the contribution of feed and algae intake just as spitting out of feed are presented to clarify the results.
Below the results of the analysis of the individual diets consisting of the different plant leaves and breweries waste are compared. The tables are showing the types of food-mixtures from left to right with increasing amount of leaves or rather falling share of breweries waste with the results of the statistical analysis (typical/ atypical or not significant behavior). The first column is displaying the codes for the habits/ actions (as described in table 4.11). As a well accepted feed Sagana (SAG) serves as reference and is presented in the first column.

Examples for desirable behaviors are “snapping feed from water column” (code “a”), “snapping feed from bottom” (code “f”), “snapping feed from surface” (code “i”) and “collecting particles from bottom” (code “l”) in contrast to unwanted behavior like “spitting feed” (code “b”) and “scraping algae” (code “q” and “r”) which indicates a lack of interest on the diet.

The figures are displaying the percentage of the individual behaviors of all analyzed diets within a feed category for a better comparability.

6.1 Cassava leaves based feed

Table 6.1 and figure 6.1 are showing for example that "snapping feed from water column" (a) is typical for CA30, CA40, not significant for CA50 and atypical for CA60, similar like the percentage values are presenting. "Collecting particles from bottom" (l) is not significant for CA30, CA40 but typical for CA50 and CA60 with a lower share of breweries waste and could be a sign for waiting for the disintegration of the pellets on the bottom of the observation tanks and then picking out the particles of breweries waste.
The percentage of the unwanted action of algae intake is also displaying a higher ratio with a decreasing content of breweries waste.

Table 6.1: Type of behavior for feeding of Cassava leaves based diets

habit	**SAG**	**CA30**	**CA40**	**CA50**	**CA60**
a	T	T	T	n.s.	AT
b	AT	AT	AT	AT	AT
d	AT	AT	AT	AT	AT
e	AT	AT	AT	AT	AT
f	T	T	T	T	n.s.
g	AT	T	T	T	n.s.
i	n.s.	AT	AT	n.s.	AT
l	AT	n.s.	n.s.	T	T
m	n.s.	T	T	T	n.s.
n	AT	AT	AT	T	AT
o	n.s.	AT	AT	AT	AT
p	AT	AT	AT	AT	AT
q	AT	n.s.	AT	n.s.	T
r	AT	AT	AT	AT	n.s.
t	n.s.	AT	AT	AT	AT
u	AT	AT	AT	AT	AT
w	T	n.s.	n.s.	n.s.	T
y	n.s.	AT	AT	AT	AT

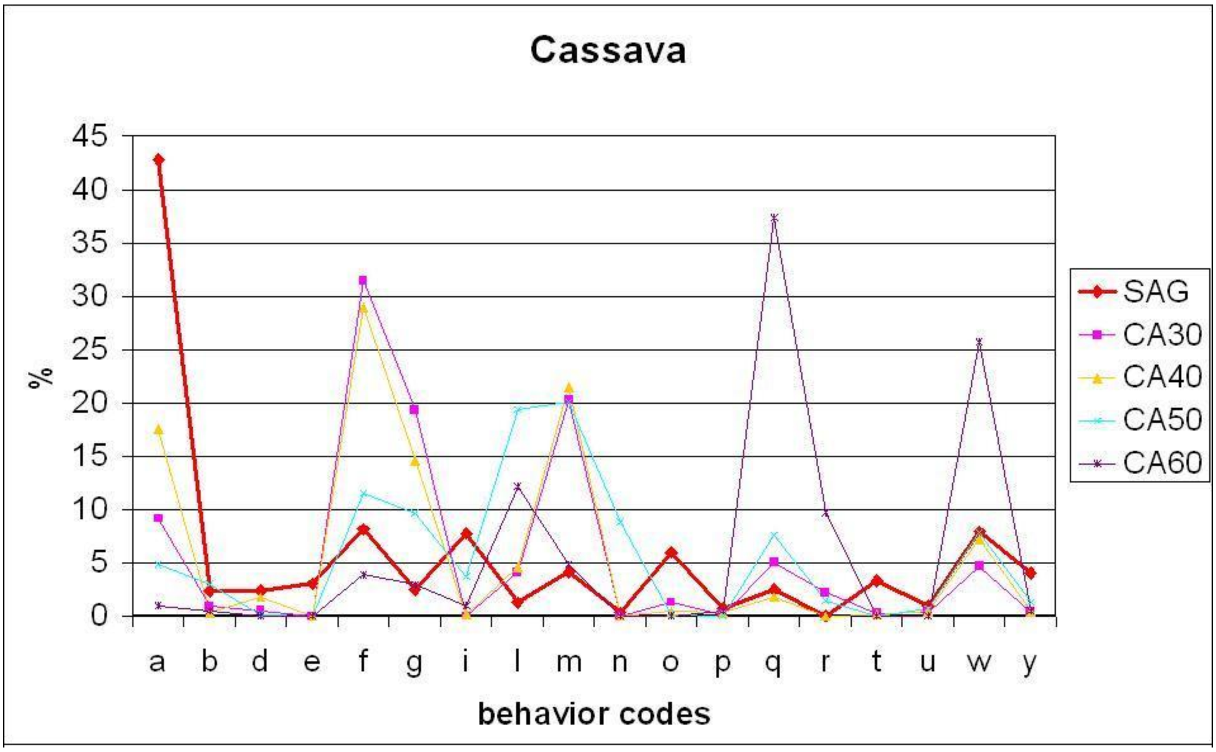

Figure 6.1: Percentage distribution of the observed behaviors by feeding of Cassava leaves based diets

6.2 Mexican sunflower leaves based feed

The behavior "snapping feed from water column" (a) is not significant for any single analyzed mixture like it is presented in table 6.2 but would be a desired behavior because it shows a certain interest in the feed when it is uptaken during sinking down. The share of "collecting particles from bottom" (l) is relatively high in comparison to "Sagana" (see figure 6.2) and mainly caused by the rapid sinking and then disintegration of the pellets meanwhile pellets of "Sagana" stayed compact for a longer time and furthermore were sinking to the ground much more slowly and therefore mostly eaten during the fall .

"Spitting feed" (b) is atypical for the reference diet, typical for MA30 and not significant for MAV and MG30. "Algae intake" (q) is typical for one tested mixture and not significant for the other ones but still with a higher share as it is with "Sagana".

Table 6.2: Type of behavior for feeding of Mexican sunflower leaves based diets

habit	SAG	MA30	MAV	MG30
a	T	n.s.	n.s.	n.s.
b	AT	T	n.s.	n.s.
d	AT	AT	AT	AT
e	AT	n.s.	AT	AT
f	T	T	n.s.	T
g	AT	AT	n.s.	AT
i	n.s.	AT	AT	n.s.
l	AT	T	T	T
m	n.s.	n.s.	n.s.	n.s.
n	AT	AT	AT	AT
o	n.s.	AT	AT	AT
p	AT	AT	AT	AT
q	AT	n.s.	T	n.s.
r	AT	n.s.	AT	n.s.
t	n.s.	AT	AT	AT
u	AT	AT	AT	n.s.
w	T	T	T	T
y	n.s.	AT	AT	AT

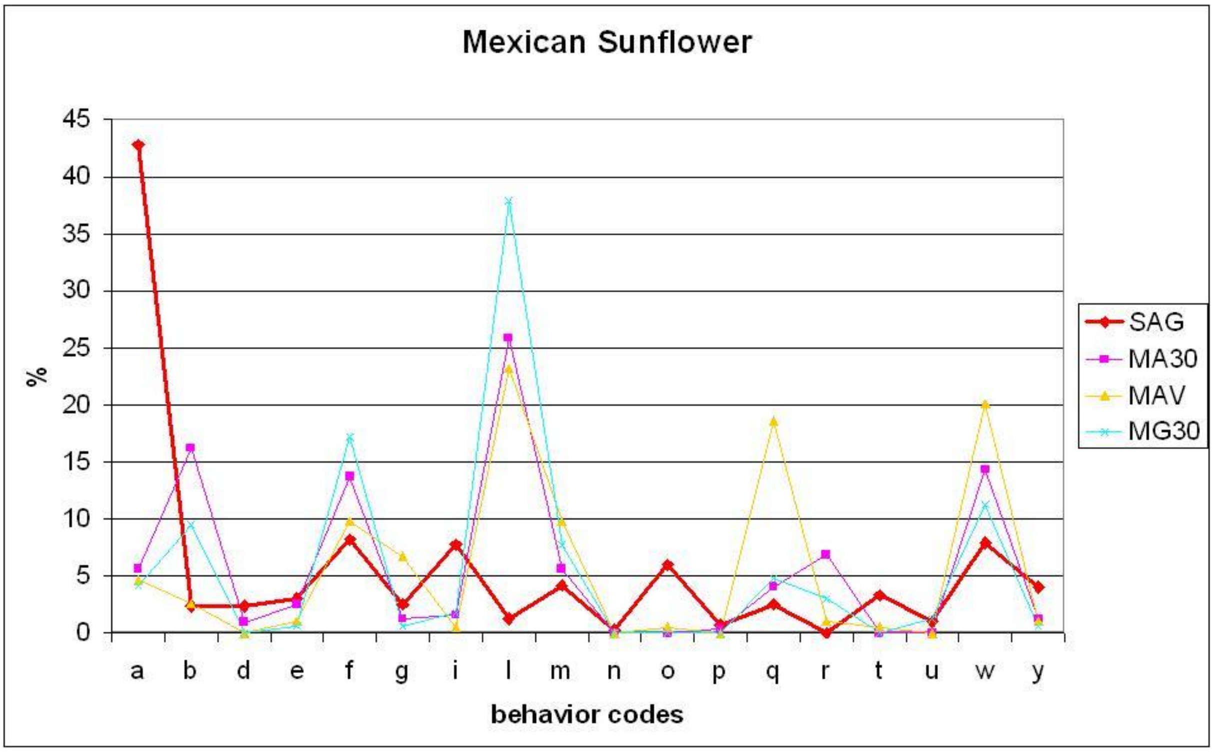

Figure 6.2: Percentage distribution of the observed behaviors by feeding of Mexican sunflower leaves based diets

6.3 Sweet potato leaves based feed

In table 6.3 it is presented that “scraping algae of the wall” (q) is typical for all diets of Sweet potato with one exception, SA30. The share of “snapping feed from water column” (a) is relatively low in comparison to the reference feed like it is displayed in figure 6.3 and is showing an atypical or rather not significant behavior within all analyzed diets like also “snapping feed from surface” (i). “Snapping feed from bottom” (f) is typical in nearly all feed mixtures. SG40 and SA50 are presenting a considerable high ratio of “grazing the surface” (n) which indicates remaining floating particles on the surface.
It can not be read clearly that the acceptance increases with an increasing proportion of breweries waste.

Table 6.3: Type of behavior for feeding of Sweet potato leaves based diets

habit	**SAG**	**SA30**	**SA40**	**SA50**	**SA70**	**SAV**	**SG40**
a	T	AT	n.s.	n.s.	n.s.	AT	AT
b	AT	AT	AT	n.s.	AT	AT	AT
d	AT	AT	n.s.	AT	AT	AT	AT
e	AT	AT	AT	AT	AT	AT	AT
f	T	T	T	n.s.	T	T	T
g	AT	T	n.s.	T	n.s.	T	n.s.
i	n.s.	AT	AT	n.s.	AT	AT	AT
l	AT	n.s.	n.s.	AT	T	AT	T
m	n.s.	T	n.s.	T	n.s.	T	T
n	AT	n.s.	AT	T	AT	n.s.	T
o	n.s.	AT	AT	AT	n.s.	AT	AT
p	AT	AT	AT	AT	n.s.	AT	AT
q	AT	AT	T	T	T	T	T
r	AT	AT	n.s.	AT	n.s.	AT	AT
t	n.s.	AT	AT	AT	AT	AT	AT
u	AT	AT	AT	AT	AT	AT	AT
w	T	n.s.	T	T	T	n.s.	n.s.
y	n.s.	AT	AT	AT	n.s.	AT	AT

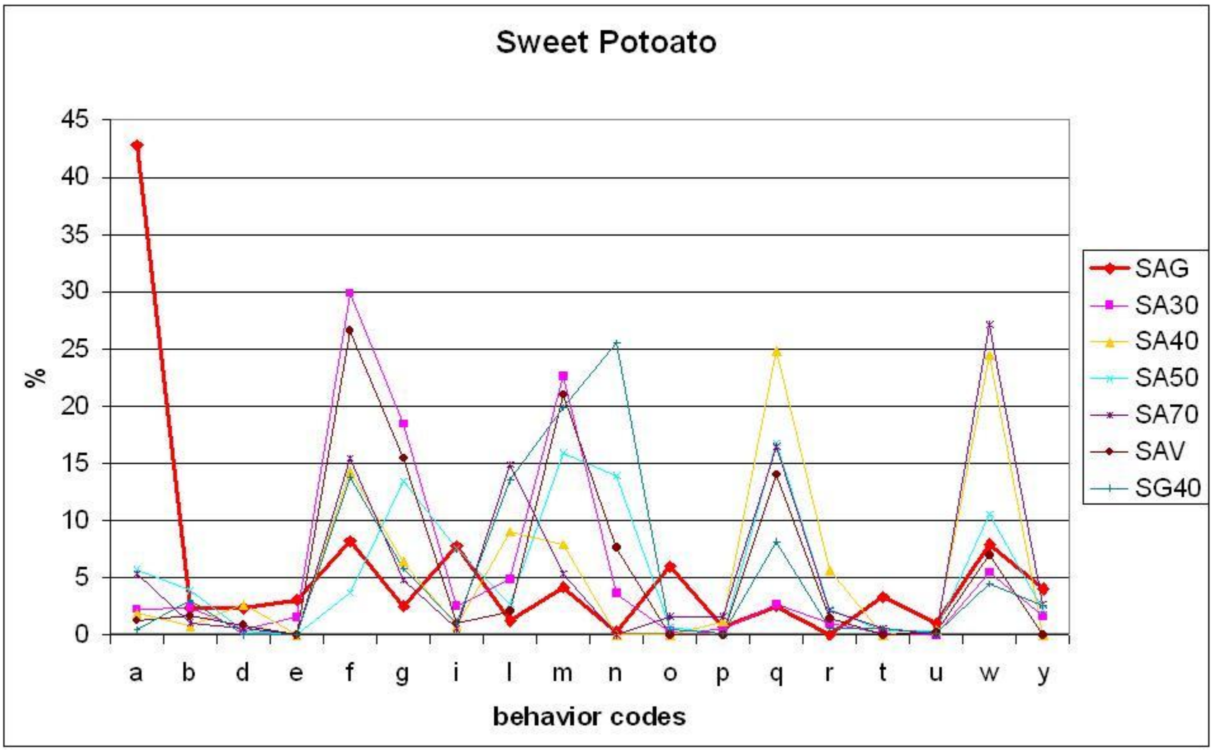

Figure 6.3: Percentage distribution of the observed behaviors by feeding of Sweet potato leaves based diets

6.4 Comparison of all feed categories

Table 6.4 and figure 6.4 are presenting an overview of all feed categories and it can be read that "snapping feed from water column" (a) is only typical for Cassava leaves based feeds, atypical for Sweet potato and not significant for Mexican sunflower. Cassava is showing the highest share of "snapping feed from bottom" (f) as well as "spitting particles through gills" (m).
The highest ratio of "scraping algae" (q) was observed within the Sweet potato category in almost the same manner as "grazing the surface" (n).

Table 6.4: Comparison all feed groups

habit	**SAG**	**CAS**	**MSF**	**SPL**
a	T	T	n.s.	AT
b	AT	AT	T	AT
d	AT	AT	AT	AT
e	AT	AT	AT	AT
f	T	T	T	T
g	AT	T	AT	T
i	n.s.	AT	AT	AT
l	AT	T	T	T
m	n.s.	T	n.s.	T
n	AT	AT	AT	T
o	n.s.	AT	AT	AT
p	AT	AT	AT	AT
q	AT	T	T	T
r	AT	AT	n.s.	AT
t	n.s.	AT	AT	AT
u	AT	AT	AT	AT
w	T	T	T	T
y	n.s.	AT	AT	AT

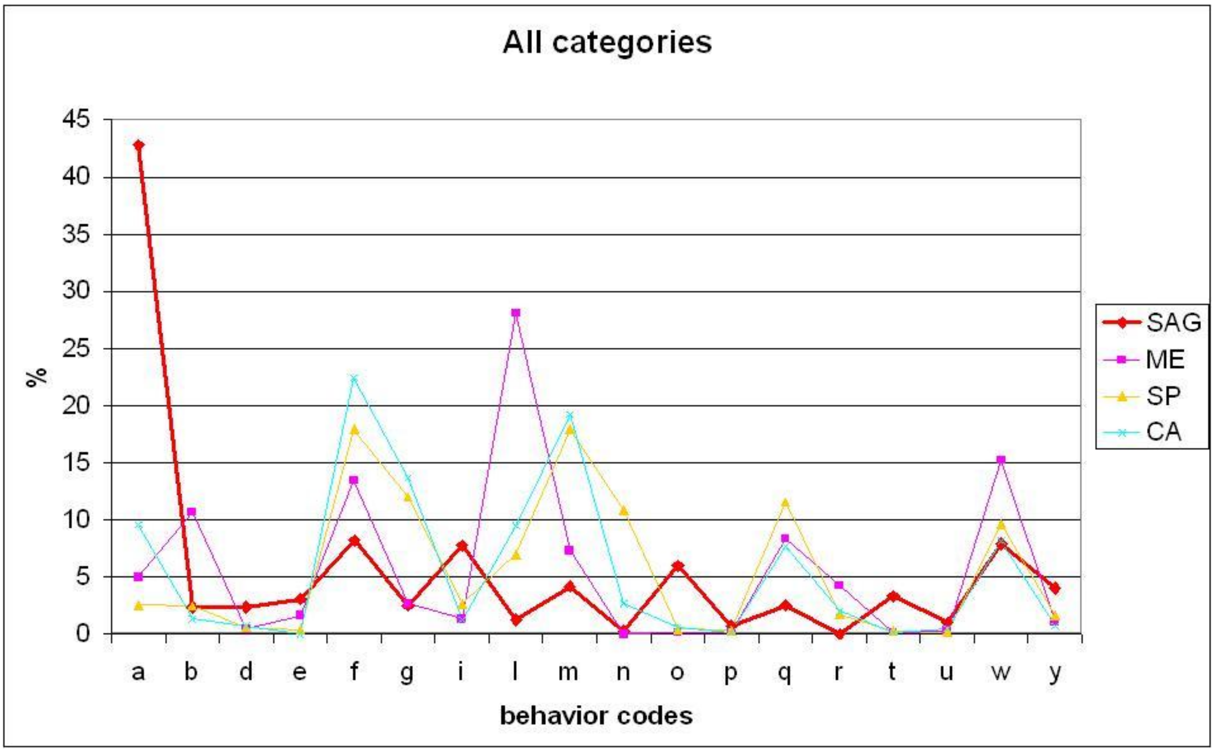

Figure 6.4: Percentage distribution of the observed behaviors of all feed groups

6.5 Comparison of different feeding habits

Figure 6.5 is displaying the different shares of “spitting out of feed”, “ingestion of algae” and “ingestion of feed” of the different feed categories as well as of “Sagana”, the reference feed. For the underlying data see Appendix table A.5.
“Spitting out of feed” includes the individual actions of “b”, “m” and “y”, “ingestion of feed” involves the single habits of “a”,“e”, “f”, “i”, “l” and “n” meanwhile “ingestion of algae” summarizes the intake of algae from the bottom and the walls of the observation tanks.
The different hatchings are showing whether it is an atypical, typical or an habit without statistical significance.
For example for the intake of algae it can be assumed that their preference to the feed is a sign for not so well acceptance of the diet.
If the share of feed intake is much bigger than algae intake or spitting out of feed, it is a clear sign for good acceptance of the fodder like the presented results of “Sagana” show. During observation also “spitting out of feed” was monitored but mostly new or crushed pellets were uptaken immediately.
The category of Cassava diets is also displaying a relatively high share of feed intake in comparison to algae intake. “Spitting out of feed” was observed more frequently, mostly in connection with “chewing” and the spitting of small particles. It is assumed that mainly the content “breweries waste” was filtered out of the feed.
Mexican sunflower leaves based diets are presenting the highest percentage of algae intake with a frequency of 46.9% of the included observations. Most of the uptaken pellets were spat out immediately. The behavior pattern of chewing and spitting out of small particles, like mentioned before, could also be dedected.
The typical behavior of feed intake with a share of 54.0% is displayed within the feed category of Sweet potato leaves based feeds. This category behaves similarly like “Cassava”, with the exception of a larger ratio of algae intake.

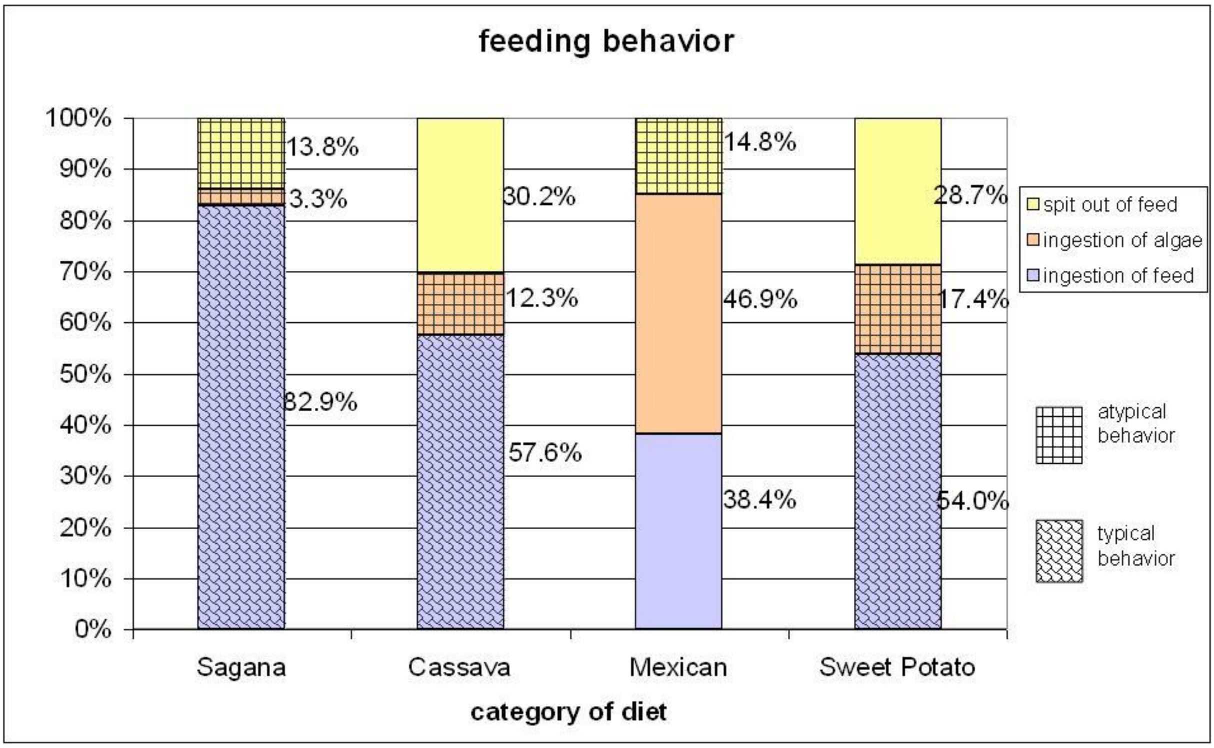

Figure 6.5: Comparison feeding habits

6.6 Comparison number of activities of feed intake

The pie chart shown below (figure 6.6) is presenting the average counts of observed activities of feed intake (the sum of “snapping feed from water column”, “snapping small particles”, “snapping feed from bottom”, “snapping feed from surface”, “collecting particles from bottom” and “grazing the surface”) per individual feed mixture within the feed categories (Mexican sunflower, Cassava and Sweet potato leaves based feeds as well as Sagana diet). In general one can say that a higher number of feed intake observations is showing a higher interest in the diet. The highest number was observed within the Cassava group with an average of 268 counts, due to the very often performed behavior pattern of feed intake- chewing- spitting out of particles.
During the 8-minute sequences, by feeding “Sagana” it was monitored that as much feed as possible was uptaken during the first one or two minutes and then only the action of “chewing” was performed, therefore there are not as many activities accounted as perhaps expected due to the very good acceptance of the feed. Furthermore it has to be noted that there was no distinction made in the size of the feed. In general, the pellets of Sagana were larger than for the produced mixtures and therefore not so many of them could be taken by the fish.
The lowest number are showing the Mexican sunflower leaves based feeds with an average of only 113 per feed and thus indicates less interest/ acceptance in the given diets. Feed was tried several times but then ignored completely.
“Sweet potato” is presenting with an average number of 202 habits per feed lower values than “Cassava” and higher ones than “Mexican sunflower”.

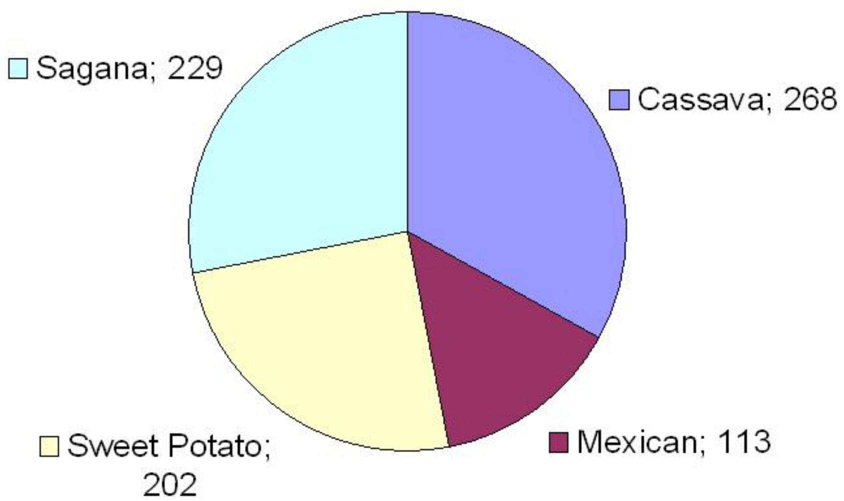

Figure 6.6: Number of activities of feed intake

Chapter 7

Summary

The main objectives of this study were to find out how the produced food was accepted by the fish and to examine its properties like the descent rate and therefore the applicability in the small-scale cage aquaculture.

Overall it can be concluded that no diet can reach the characteristics of “Sagana”, neither in the acceptance, nor concerning the consistency or even the sinking rate.

Diets containing Mexican sunflower were accepted worst which is proofed by the largest proportion of “spitting feed” and also the quite high share of “algae intake”. Observed, but not evaluated statistically, was the fact that the diets were completely ignored and not even tried after several feedings. The low average number of activities indicates a lack of interest. The really high proportion of “chasing another fish” points to aggression and hunger.

For the mixtures with Cassava leaves it was clearly shown that they were better accepted with an increasing content of breweries waste. Feed intake mainly took place from the bottom of the tanks in the form of picking whole pellets instead of small particles which is probably due to the too rapid sinking of them.

Feeding of sweet Sweet potato diets led to similar actions as feeding Cassava ones. This was shown by the often observed behavior pattern of feed intake (mainly particles) followed by a longer period of chewing and then by spitting particles. One difference is presented, namely that grazing the surface was observed more often, but less often than feed intake from the water column and the bottom. This can be explained on the one hand that the consistency was not as good, pellets disintegrated faster and particles remained swimming at the water surface and on the other hand that the interest in the food was not so big.

Concerning the descent rate of the produced mixtures, no difference between the used binders gelatine and argartine was observable. A different amount of used binders resulted on the one hand in a fast disintegration when only a small proportion was used meanwhile on the other hand a too high proportion of binder brought in addition to the rapid sinking, because of the higher weight, the effect that the pellets were very hard and therefore difficult for the fish to

chew.
Due to the fast sinking, further tests should be conducted whether there are ways to keep the pellets on the bottom of the cage, for example by using a tile or denser net material.

According to [EL-SAYED, 2006] feed for Tilapia should have a share of crude protein between 20 to 30% of the dry matter and a crude lipid content of 15%. Table 7.1 is showing the average of the calculated nutrition contents of the used plant leaves as well as for breweries waste after [GUTMANN, prep] in comparison to those recommended in literature.

Table 7.1: Data for crude protein and crude lipid

	Crude protein [in % of DM]	Crude lipid [in % of DM]
recommendation [EL-SAYED, 2006]	20.0 - 30.0	15.0
Breweries waste	28.0	15.2
Cassava leaves	28.8	15.0
Mexican sunflower leaves	30.4	14.2
Sweet potato leaves	25.7	9.8

With the exception of Sweet potato leaves, all components which were used for producing the diets were showing values close to the recommended ones concerning the content of crude lipid.
Regarding the percentage of required crude protein, all investigated parts are having values between 20 to 30%. Leaves of Mexican sunflower have the highest share with 30.4 % but are accepted worst which is assumed to have its causes in the high amount of bittern in the plant-material. It should be further investigated if there is a possibility to reduce this bitterness in a simple way.

Concluding, there can be made the statement that feed mixtures with breweries waste (exception Mexican sunflower leaves) are accepted better and are qualified as diet in Tilapia small-scale cage culture but further investigation should be done concerning the descent rate of pellets and their consistence.

Appendix A

Appendix

Table A.1: Data for figure 1.2 "Aquaculture in Kenya"

year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
tons	180	200	200	250	270	300	320	350	370	350	380	410	360
year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
tons	380	430	399	370	360	317	293	240	220	170	180	160	150
year	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
tons	160	160	180	160	160	160	195	201	207	213	224	210	561
year	1990	1989	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
tons	1236	972	1178	1136	1145	1385	1302	579	199	153	300	512	1009
year	2002	2003	2004	2005	2006	2007							
tons	798	1012	1035	1047	1012	4240							

Table A.2: Data for figure 3.4 "Global Aquaculture production for *Oreochromis niloticus*"

year	1950	1951	1952	1953	1954	1955	1956	1957
tons	1.590	2.120	2.629	3.312	4.499	5.140	5.381	7.891
year	1958	1959	1960	1961	1962	1963	1964	1965
tons	8.035	8.628	7.736	6.521	6.300	7.189	8.179	9.169
year	1966	1967	1968	1969	1970	1971	1972	1973
tons	9.457	9.458	9.855	11.059	12.058	13.602	14.923	16.786
year	1974	1975	1976	1977	1978	1979	1980	1981
tons	18.422	20.246	24.940	28.454	32.871	35.300	41.357	45.733
year	1982	1983	1984	1985	1986	1987	1988	1989
tons	51.116	60.434	66.660	89.989	111.649	124.413	129.794	201.040
year	1990	1991	1992	1993	1994	1995	1996	1997
tons	233.601	255.221	328.092	378.441	425.500	520.191	624.841	705.498
year	1998	1999	2000	2001	2002	2003	2004	2005
tons	719.596	823.035	967.842	1.030.888	1.112.834	1.270.085	1.454.770	1.660.371
year	2006	2007						
tons	1.889.277	2.121.000						

Table A.3: Quantiles of the chi-square distribution with n degrees of freedom and the level of significances in %

degrees of freedom	10%	5%	2.5%	1%	0.5%	0.1%
1	2,71	3,84	5,02	6,63	7,88	10,83
2	4,61	5,99	7,38	9,21	10,60	13,82
3	6,25	7,81	9,35	11,34	12,84	16,27
4	7,78	9,49	11,14	13,28	14,86	18,47
5	9,24	11,07	12,83	15,09	16,75	20,52
6	10,64	12,59	14,45	16,81	18,55	22,46
7	12,02	14,07	16,01	18,48	20,28	24,32
8	13,36	15,51	17,53	20,09	21,95	26,13
9	14,68	16,92	19,02	21,67	23,59	27,88
10	15,99	18,31	20,48	23,21	25,19	29,59
11	17,28	19,68	21,92	24,73	26,76	31,26
12	18,55	21,03	23,34	26,22	28,30	32,91
13	19,81	22,36	24,74	27,69	29,82	34,53
14	21,06	23,68	26,12	29,14	31,32	36,12
15	22,31	25,00	27,49	30,58	32,80	37,70
16	23,54	26,30	28,85	32,00	34,27	39,25
17	24,77	27,59	30,19	33,41	35,72	40,79
18	25,99	28,87	31,53	34,81	37,16	42,31
19	27,20	30,14	32,85	36,19	38,58	43,82
20	28,41	31,41	34,17	37,57	40,00	45,31
21	29,62	32,67	35,48	38,93	41,40	46,80
22	30,81	33,92	36,78	40,29	42,80	48,27
23	32,01	35,17	38,08	41,64	44,18	49,73
24	33,20	36,42	39,36	42,98	45,56	51,18
25	34,38	37,65	40,65	44,31	46,93	52,62
26	35,56	38,89	41,92	45,64	48,29	54,05
27	36,74	40,11	43,19	46,96	49,65	55,48
28	37,92	41,34	44,46	48,28	50,99	56,89
29	39,09	42,56	45,72	49,59	52,34	58,30
30	40,26	43,77	46,98	50,89	53,67	59,70
31	41,42	44,99	48,23	52,19	55,00	61,10
32	42,58	46,19	49,48	53,49	56,33	62,49
33	43,75	47,40	50,73	54,78	57,65	63,87
34	44,90	48,60	51,97	56,06	58,96	65,25
35	46,06	49,80	53,20	57,34	60,27	66,62
36	47,21	51,00	54,44	58,62	61,58	67,98
37	48,36	52,19	55,67	59,89	62,88	69,34
38	49,51	53,38	56,90	61,16	64,18	70,70
39	50,66	54,57	58,12	62,43	65,48	72,05
40	51,81	55,76	59,34	63,69	66,77	73,40
50	63,17	67,50	71,42	76,15	79,49	86,66
60	74,40	79,08	83,30	88,38	91,95	99,61
70	85,53	90,53	95,02	100,43	104,21	112,32
80	96,58	101,88	106,63	112,33	116,32	124,84
90	107,57	113,15	118,14	124,12	128,30	137,21
100	118,50	124,34	129,56	135,81	140,17	149,45
150	172,58	179,58	185,80	193,21	198,36	209,26

Table A.4: Data for figure 5.21

average o	SAG	CAS	MSF	SPL	
surface	29	22.8	3.0	66.0	
water column	154.5	56.5	11.3	12.3	
bottom	34	188.5	94.7	121.5	
sum	218	268	109	200	794
%	SAG	CAS	MSF	SPL	
surface	13.3	8.5	2.8	33.0	
water column	71.0	21.1	10.4	6.2	
bottom	15.6	70.4	86.9	60.8	
sum	100.0	100.0	100.0	100.0	
e	SAG	CAS	MSF	SPL	
surface	66.17	66.17	66.17	66.17	
water column	66.17	66.17	66.17	66.17	
bottom	66.17	66.17	66.17	66.17	
sum	198.50	198.50	198.50	198.50	794.00
$u = (b - e)/\sqrt{e}$	SAG	CAS	MSF	SPL	
surface	-4.57	-5.34	-7.77	-0.02	
water column	10.86	-1.19	-6.74	-6.62	
bottom	-3.95	15.04	3.50	6.80	
T/ AT	SAG	CAS	MSF	SPL	
surface	AT	AT	AT	n.s.	
water column	T	n.s.	AT	AT	
bottom	AT	T	T	T	

Table A.5: Data for table 6.5

average o	SAG	CAS	MSF	SPL	
ingestion of feed	228.5	267.8	112.7	201.7	
ingestion of algae	9.0	57.0	137.7	64.8	
spit out of feed	38.0	140.3	43.3	107.2	
sum	275.5	465.0	293.7	373.7	1408

%					
ingestion of feed	82.9%	57.6%	38.4%	54.0%	
ingestion of algae	3.3%	12.3%	46.9%	17.4%	
spit out of feed	13.8%	30.2%	14.8%	28.7%	
sum	1.0	1.0	1.0	1.0	

e	SAG	CAS	MSF	SPL	
ingestion of feed	117.32	117.32	117.32	117.32	
ingestion of algae	117.32	117.32	117.32	117.32	
spit out of feed	117.32	117.32	117.32	117.32	
sum	351.96	351.96	351.96	351.96	1408

$u = (b - e)/\sqrt{e}$	SAG	CAS	MSF	SPL	
ingestion of feed	10.26	13.89	-0.43	7.79	
ingestion of algae	-10.00	-5.57	1.88	-4.85	
spit out of feed	-7.32	2.12	-6.83	-0.94	

T/ AT	SAG	CAS	MSF	SPL	
ingestion of feed	T	T	n.s.	T	
ingestion of algae	AT	AT	n.s.	AT	
spit out of feed	AT	n.s.	AT	n.s.	

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