FEEDING LEVEL EFFECT ON THE GROWTH OF RAINBOW TROUT (*Onchorynchus mykiss*) FINGERLINGS

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ABSTRACT

Rainbow trout is farmed in many countries all over the world. A balanced diet and proper feeding practices are important in aquaculture. It is necessary to have a proper amount of feed with ingredients necessary for fish such as protein for normal tissue function, maintenance and renewal of the fish body, carbohydrates and lipids for energy source, vitamins and minerals for body functions, growth, reproduction and maintenance of fish metabolism. Overfeeding, insufficient feeding, fish diseases and feed waste are the main challenges faced during fish feeding operations, which can also result in economical challenges.

An experiment conducted at the Fish Research Unit of the University of Eastern Finland in the Department of Biology in the summer 2010, aimed to evaluate the physical changes of rainbow trout (*O. mykiss)* fingerlings fed at different levels, one group at a minimum level and the second group at an optimum level.

After a six week feeding trial, the weight and length of fingerlings increased in the optimum feeding group compared to the minimum feeding group. The feed conversion ratio (FCR) was lower in the minimum feeding group, than in the optimum feeding group but differences were not significant (p=1.000). Fat deposition in the abdominal cavity found in some juveniles was most likely to fish having consumed more feed. The specific growth rate was lower in the minimum feeding group than in the optimum feeding group, but there were no significant differences between the groups (p=0.100).

A lower FCR means that fish utilized the feed better. If the FCR is higher than the optimum level it implies that feed is being wasted. Fish should be sorted according to size to avoid competition and dominancy issues during the feeding. It is important to feed fish with proper feed containing the required nutrients, follow feeding instructions taking into consideration light and temperature factors, feed fish with a proper amount of feed and to choose a proper method of feeding to get optimal results in the development of the body weight and length of the fish.

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АННОТАЦИЯ

Радужную форель вырашивают во многих странах по всему миру. Сбалансированная питание и правильное кормление играют важную роль в аквакультуре. Корм должен состоять из правильного колличества ингридиентов котороые необходимы для рыб, такие как белки для функции тканей а также поддержание и обновление тел у рыб, углеводы и липиды для источника энергии, витамины и минералы для функционирования организма и роста, а также для размножения и поддержания метаболизма рыб. Перекармливание, недостаточное кормление, болезни рыб и кормовые отходы являются основными проблемами возникающими во время кормления рыб, которые также могут привести к финансовым проблемам.

Эксперимент, был проведен в Исследовательском Центре рыб рядом с Университетом Восточной Финляндии на кафедре Биологических наук, летом 2010 года. Цель эксперимента было определение физических изменений тела, мальков радужной форели (*O.mykiss)* в течение шести недель кормления между группами минимального и оптимального кормления.

После шести недель кормления, вес и рост мальков в группе оптимального кормления увеличились, по сравнению с группой минимального кормления. Кормовой Коэффициент Рациона (ККР) была ниже в группе минимального кормления, по сравнению с группой оптимального кормления, но значительное различие не обнаружено между группами ($p = 1{,}000$). Накапливание жира в брюшной полости было обнаружено у некоторой мальков, скорее всего у тех рыб, которые употребили больше корма . Удельная Скорость Роста (УСР) было ниже в группе минимального кормления чем в группе оптимального кормления, но значительное различие не было обнаружено между группами ($p = 0{,}100$).

Если ККР будет ниже стандарта то употребление корма будет лучше. Если ККР будет выше определенного уровнья, то корм тратится впустую. Рыба должна быть отсортирована по размеру, чтобы избежать конкуренции и доминирования между рыб во время кормления. Важно что корм должна быть выбрана правильно, с содержанием необходимых питательных веществ, следовать инструкции кормления, кормить рыб с правильным количеством корма и определить правильный метод кормления, для того, чтобы в результате достичь оптимальных результатов в развитии массы тела и роста рыбы.

ACKNOWLEDGMENTS

The feeding experiment did not only touch on the feeding of fish. I also discovered the main principles and ideas of fish farming. It was interesting to learn and gain skills which are necessary for my future specialization.

The feeding trial began in summer 2010, supervised by Jouni Heikkinen of the University of Eastern Finland and it lasted six weeks. The rainbow trout fingerlings brought from a private fish farm, Savon-Taimen Ltd. and were kept at Fish Research Unit. The fingerlings were fed, measured, reared and managed in Fish Research Unit by students and workers of research unit. The fish feed was provided by Biomar feed company. The feeding experiment was funded by the Food and Agriculture Organization of the United Nations (FAO) together with University of Eastern Finland (UEF).

I am sincerely thankful to my supervisors Jouni Heikkinen and Roseanna Avento. Thank you for your tireless patience. I remember when I started to study at UEF, I did not know many things but you helped me a lot and had the patience to guide me and assist me to complete my degree. I would like to give thanks to my teachers Paula Henttonen and Liisa Nurminen. Your lectures were always the best, and I learned many skills regarded to my specialization. Thank you to Professor Atte von Wright for the lectures and support.

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The study period in Finland gave me a lot of possibilities to further my future and opened the door of science. During the studies, my main challenge was the English language but I worked hard and achieved my purpose. I went through a lot of difficulties and finished my degree because of all of your support and help. I am very satisfied and proud of completing my Master degree in Aquaculture, fisheries and fish processing.

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1. INTRODUCTION

Managing fish nutrition is important to achieve optimal development of body weight and to maintain the health of fish. In fish husbandry, the maximum economic return, achieving optimal growth and production efficiently depends on fish nutrition (Anderson & Silva, 2003).

Fish require several types of nutrients to maintain body functions and their health. Fish must also be fed appropriately, obtain sufficient amount and mix of nutrients from feed, which should contains protein for normal tissue function and its renewal, lipids and carbohydrate as a source of energy, ash, phosphorus, water and a small amount of vitamins and minerals for different body functions, as well as growth, reproduction and maintenance of fish metabolism (Graig and Helfrich, 2009). Fish growth and feed conversion ratio is also influenced by different factors such as quality of feed, feed intake and water temperature (Watanabe, 1988).

Many types of fish feed are currently available, for example different types of wet, moist feed, steam and plant extruded dry pellets. Most fish farms use either dry or moist pellets that contain all the necessary nutrients.

It is important to know how to properly feed fish and it is necessary to choose appropriate methods for feeding. Feeding fish with a proper amount of feed is very important in order to avoid challenges, which can arise from overfeeding or insufficient feeding. According to Masser and Cline. (1990), overfeeding is costly, wastes feed, and can cause water quality problems, which can lead stress and disease. In addition, overfeeding leads to shortage of oxygen especially in hot weather and increased biological oxygen demand. Insufficient feeding slows the growth of fish reducing production efficiency and profitability. Furthermore, insufficient feeding can limit the growth potential of fish and decrease feed conversion ratio (Bureau et al., 2006).

The growth of fish and feed conversion rate are dependent on species, genetic strain, sex, stage of reproductive cycle, etc., and it leads different nutritional requirements. Growth i also affected by quality of diet, energy content, nutrient balance and etc., as well as environmental condition such as water temperature, oxygen content, water flow rate, etc (Shepherd, 1988).

This feeding experiment was completed at the Fish Research Unit of the University of Eastern Finland, Department of Biology in the summer 2010. The aim of the experiment was to measure the effect of different feeding levels on the growth parameters of rainbow trout (*O. mykiss*) fingerlings.

The feeding experiment is important to determine the physical changes in rainbow trout fingerlings over the period presented, and the influence of feeding methods on fish growth.

2. LITERATURE REVIEW

2.1 RAINBOW TROUT (*O.mykiss*)

Rainbow trout (*O.mykiss*) is a freshwater fish from the family salmonidae. The biological features of rainbow trout include 60-66 vertebrae, 3-4 dorsal spines, 10-12 dorsal soft rays, black, small spots on the back, head and fins but the coloration depends on habitat, size and sexual condition (Cowx, 2005).

Rainbow trout is native to the freshwater rivers and lakes of the pacific coasts of the North America and Asia. It has been introduced to around 82 countries, generally almost everywhere in the world, because it can tolerate a wide range of environments and its production condition is better than other trout species (Woynarovich et al., 2011).

The scientific classification and taxonomy of rainbow trout (Starnes, 2003):

- Order→ *Salmoniformes* (salmons)
- Family→ *Salmonidae* (samonids, salmons)
- Species → *Oncorhychus mykiss* (rainbow trout, red band trout)

Rainbow trout spawn between autumn and spring, and mature females produce 2000 ova per kilogram body weight (Purser and Forteath, 2003). Males mature at 2 years but majority of females mature at 3 years. Optimum temperatures for growth after hatching are between +12-+18°C (Purser and Forteath, 2003)

2.2 NUTRITION AND FEEDING

Nutrition is the science of feeding to get optimal and sufficient development of fish body weight, energy and health maintenance (Anderson & Silva, 2003). Formulation of a balanced diet and appropriate feeding are the two most important requirements of aquaculture. Without correct and suitable feed, fish are unable to stay healthy and productive (Watanabe, 1988). Research, quality control and biological evaluation are important to formulate diets correctly (Watanabe, 1988).

To understand and deliver an optimal balance of nutrients to fish, nutritionists must understand the process of ingestion, digestion, absorption and metabolism (Anderson & Silva, 2003) (Table 1).

Table 1. Processes in delivery of nutrients in fish

PROCESS	DESCRIPTION
Ingestion	Ingestion is the process of consuming food or taking it into the body.
Digestion	“Digestion is the mechanical and chemical processing of feed in the gastrointestinal tract where the feed is broken down into compounds that can be assimilated by the body. Digestion is performed primarily by digestive enzymes, which are secreted into the lumen of the alimentary canal” (Anderson & Silva, 2003).
Absorption	Nutrient absorption occurs when the “products of digestion” are absorbed into the body cells through active transport and diffusion” (Anderson & Silva, 2003).“It is an energy requiring process and can occur either as facilitated or as simple diffusion” (Anderson & Silva, 2003). Simple diffusion moves molecules from one area of higher concentration to an area of lower concentration without input of energy. Facilitated diffusion is following the same rules but uses protein carrier molecules to allow substances that are fat soluble to diffuse through the cell membrane (Anderson & Silva, 2003).
Metabolism	The metabolism in fish is providing energy to power critical body processes or building and maintaining the body parts needed to function. The word “metabolism” describes the catabolic and anabolic reactions, which can occur within organism to result in energy and growth. (Anderson & Silva, 2003).

2.2.2 Fish feed

Fish feeds maybe classified as wet, moist or dry depending on their moisture content (Goddard, 1996; Jobling, 1994; Hardy, 1989). Wet and moist feed consist of ground or frozen fish, fish-processing waste and has a moisture content of 50-70%. Moist feed has a moisture content of 35-40%. Dry feed contains less than 10% moist and is made from fish meal, cooked starch, vitamin and minerals premixes and alginate binder (Jobling et al., 2001 b).

Fish feed processing methods that dominate the feed sector result in the following types of feed: extruded, expanded and compressed feed:

Compressed feed are produced when feed ingredients are compressed together to produce dense feed. Steam is added to the dry feed ingredients, increasing the moisture content to 15-20%. During manufacture, the temperature is usually raised to 70-85°C in order to cause gelatinization of starch and help in the binding of the feed ingredients. After the mixture passes through a feed die the moisture content is reduced by forcing air over the warm feed. In addition, lipids can be spread onto the feed after pelleting and moisture level can be achieved up to 16-20% (Jobling et al., 2001 b).

Expanded feeds are makes the feed porous, better binding the feed and more digestible starch and protein. The degree of starch gelatinization obtained by expansion can exceed 60%, microbial content of the mixture can be significantly reduced, and there is the possibility of adding liquid such as oils and molasses (Jobling et al., 2001b).

Extruded feeds are those feeds which have been pressed, pushed or protruded through orifices under pressure" (FAO, 2001). Extruded feeds are more expensive because of higher manufacture costs. Extruded granules can float on the surface of water for a long time as they are water-resistant (FAO, 2001).

2.2.3 Contents of fish feed

Feed contains different ingredients such as protein, carbohydrates, lipids, minerals and vitamins which are necessary for fish (Southgate, 2003). One of the most feed ingredients is protein and protein is the main constituent of the tissues and organs of the fish. Proteins are made up of carbon (50%), nitrogen (16%), oxygen (21, 5%), and hydrogen (6, 5%) (Graig and Helfrich, 2009). Protein is important for normal tissue function, for maintenance and renewal of the fish body. Fish must attain protein from fish feed, and fish feed generally has about a

30-40% protein content. Protein requirements are higher for smaller fish and when fish grow larger the protein requirements usually decrease (Graig and Helfrich, 2009). Protein requirement of fish depends on various factors such as fish size, water temperature, feeding rate, availability and quality of natural food (Watanabe, 1988). Rainbow trout protein requirements revolve around 1g/kg body weight per day for tissue and 12g/kg body weight per day for maximum body protein retention (Watanabe, 1988).
Carbohydrates (starches and sugars) are the most economical and inexpensive source of energy in the fish diet. Carbohydrates are divided into three groups: - monosaccharide's (simple sugars), oligosaccharides (sugars) and polysaccharides. Mostly polysaccharides are present in feed and feedstuffs including starch cellulose (Jobling, 2001b). In fish, carbohydrates can be used as an energy source or as a rapid energy reserve stored as glycogen in the liver and muscles than can be mobilized to satisfy energy demands (Watanabe, 1988). Fish feed contains 10-15% carbohydrates and can be function as a feed binder (Watanabe, 1988). The most important carbohydrates in fish diets are starch, chitin sucrose and cellulose, and a big amount of these ingredients are found in fish feed (Anderson & Silva, 2003).

Lipids are high-energy compounds that can supply twice as much energy to the body than protein and carbohydrates (Graig and Helfrich, 2009). Fish feed is about 15% lipids (Graig and Helfrich, 2009). Recently, there is an increase in the usage of higher levels of lipids in fish feed (Graig and Helfrich, 2009). Although increasing the amount of lipids in fish diets can help to reduce high costs, the excessive fat deposition in fish liver can impact health adversely and lower marketability of fish (Graig and Helfrich, 2009). In fish feed the content of lipid for adult fish is generally higher than that for juvenile fish.

Fish utilize lipids for energy, for cellular structure and for maintenance of the integrity of bio membranes (Watanabe, 1988). Lipid nutrition and metabolism have been widely studied in fish species such as Salmonids, which are farmed intensively (Bell, 1998; Kanazawa, 1993; and Sargent et al., 1989).

Fatty acids are carboxylic acids with hydrocarbon chains from 4 to 36 carbons. These chains are fully saturated and can contain one or more double bonds (Nelson and Cox, 2000). Fatty acids can be classified into saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs) and highly-unsaturated fatty acids (HUFAs) (Jobling, 2001 b). The HUFA has 4 double bonds and PUFA has 2 double bonds. These fatty acids can be found in fish such as salmon (*Salmo salar*), white tuna (*Lepidocybium* *flavobrunneum*), mackerel *(Scomber scombrus)*, rainbow trout (*O,mykiss*), herring (*Clupea harengus Linnaeus*) and sardines(*Sardina pilchardus*) (Castle and Gooder, 2010).

Fish like other vertebrates require n-3 and n-6 PUFAs in their feed. Marine fish mostly require n-3 highly unsaturated fatty acids for optimal growth and health and usually the quantities are between 0.5-2.0 percent in fish feed. In comparison, freshwater fish do not require the long chain of highly unsaturated fatty acids and quantities ranging from 0.5-1.5% in feeds are sufficient (Graig and Helfrich, 2009). Fatty acids cannot be produced by freshwater fish and thus must be supplied in feed (Graig and Helfrich, 2009). It is estimated that in 2006, the aquaculture sector already used approximately 88. 5% of total fish oil production in the world (Teles, 2012).

Minerals are inorganic elements necessary for normal body functions. In fish feed there are two groups of minerals: macro-minerals and micro-minerals. Macro-minerals are sodium, chlorine, potassium and phosphorus (Graig and Helfrich, 2009). Common micro-minerals are copper, chromium, iodine, zinc and selenium. Minerals can serve the fish body in many different ways. They are a constituent of the bones and teeth, form soluble salts in blood and other body fluids and also contribute to proper functioning of muscles and nerves (Watanabe, 1988). Calcium and phosphorus for example are components of the skeleton, bones, scales and teeth of the fish and are important in physical processes including metabolism, metabolic reactions, nerve and muscle functions (Anderson & Silva, 2003).

Vitamins are micro-nutrients or organic molecules required for normal growth, reproduction, health and maintenance of fish metabolism. There are four fat-soluble and eleven water-soluble vitamins known to be required by fish (Cho, 2001). Vitamins are often not synthesized by fish and therefore must be supplied in the fish diet. The absence of vitamins in diet can lead to specific diseases in mammals and birds, but in fish many of the vitamin-deficiency symptoms are non- specific (Watanabe, 1988). A complete balanced nutrition of fish can influence not only the productivity of fish, but it can also affect the final quality of products for consumption (Konstantinov, 2000).

2.3 FEED INTAKE

Feeding in fish depends on their sensory capacities to find food, their ability to capture, handle and ingest food items and their physiology which determines how fish digest and process feed (Kestemont and Baras, 2001). Feed intake depends on pysio-chemical factors (Kestemont and Baras 2001), tank conditions and human activity and food palatability.

2.3.1 Physio-chemical factors

Physio-chemical factors can be such as light, temperature, oxygen and pH.

- **Light**

  The light in feed intake is variable and can change over a range, often and rapidly. Sunlight is the main natural source of light, while moonlight is a secondary source of light for fish, but to help visual observation in fish farms they use electric light condition. The light conditions influenced also on the depth of the water. Sometimes during the feeding if lighting is low the fish cannot catch the feed but too much light condition also make a stress on fish (Boeuf and Bail, 1999). The important issue of light in feeding it can help to fish find the feed and for visual observation of fish behavior for fish farmer.

- **Temperature**

  The temperature of water is important for feed intake in fish because when temperature of water increases, their metabolic rate and oxygen consumption is increases. In this condition the fish became more active and their rates for feed intake and digestion are increases as well (Poxton, 2003). As the temperature decreases, the metabolic rate and all other processes decreases as well. Therefore, the feeding regime must be adjusted according to prevailing temperature regime. It is very important to know the temperature tolerances of a species and to relate these to local water temperatures and climate (Poxton, 2003). The temperature of water affects the feeding rate of fish, because appetite is intensified as the water temperature increases. The water temperature during the feeding must be within+7- +18°C, outside of range, at lower or higher water temperature fish loose appetite (Woynarovich et al., 2011).

- **pH of water**

  The pH also can affect for palatably of fish but mostly in rivers and lakes the pH is stable. Rainbow trout tolerates unfavorable pH conditions differently during the various development phases of the fish". In order to develop the rainbow trout fry the range of optimal pH fluctuates between 6.5 and 8 (Woynarovich et al., 2011). Fish can be expected to die below pH 5.0 and higher than 9.0 (Poxton, 2003).

- **Oxygen**

Oxygen (O_2) dissolved in water necessary to fish as a respiration. They either originate from various life processes or dissolved from atmosphere at the surface (Poxton, 2003). The maximum oxygen level depends on the actual water temperature. At the higher temperature of water, the dissolved oxygen content is lower, and vice versa. During the incubation eggs of rainbow trout the dissolved oxygen in water should be 5-6 mg/liter, for older fish the acceptable low oxygen content may be about 4-5 mg/liter (Woynarovich et al., 2011). It is important to know because oxygen consumption will increase during and after the feeding. During these periods the demand for oxygen temporary increases (Woynarovich et al., 2011).

2.3.2 Tank conditions and human activity on feed intake

Tanks for fish farming have varying designs, colors, shapes and depths. The shape must allow good water flow to maintain water quality. Tanks with conical bottoms are considered to provide best circulation and self-cleaning properties (Appleford et al., 2003).

Routine operations on fish farms such a handling of fish, cleaning of the tanks, disease treatment can affect feeding in fish. Direct disturbances, such as weighing or transporting can reduce feed intake for several hours or days (Boujard et al., 1992). Even temporary disturbances such a movement or walking near to tanks may affect fish, though fish quickly resume feeding after these. Acute disturbances usually have negative effects on feeding but may also have positive effects. Juvenile rainbow trout reared in tanks nearby walk ways have been found to demand more feed than those in tanks which are further away from walkways (Speare et al., 1995).

2.3.4 Feed palatability

Feed palatability or acceptability refers to how fish can see, taste and smell the feed and find out to open appetite in order to ingest the feed.

Feed acceptability, palatability, depends on the ingredients of fish feed and its quality. Fish farmers must pay attention to feeding activities in order to maintain feed acceptance, observe feed cost, calculate feed conversion ratio and feed efficiencies (Graig and Helfrich, 2009).

Feed acceptance depends on the chemical, nutritional and physical characteristics of feed, which can be influenced during the processing and manufacture of the feed and choice of ingredients (Table 2).

Table 2. Feed acceptability or palatability factors

Organoleptic propertis	**Physical properties**
Appearance	Size (diameter, length and shape)
Structure/Texture	Density
Smell	
Taste	

Organoleptic factors

First the fish must able to locate the feed, then it must be attracted to it and be able to ingest it, and finally fish must be willing to ingest and swallow it. The ability of fish detect and ingest the feed can be affected by organoleptic properties (Table.2) such as color (contrast), texture (hardness) and feed density (sinking rate) (Houlihan, 2001).

- Appearance: -The ability of feed color is, the fish must find out and detect the feed according the color feed. “Feed colour are substances which are added in trace amounts to a diet or feed mixture to facilitate its ingestion (through improved visibility of feed particles) or to impart a desired colouration within the carcass of the cultured fish” (FAO, 1987). The feed color preferences may be expected to differ depending upon environmental setting, tank color and light intensity (Houlihan, 2001).
- Texture: -The texture of feed also affects palatability, with softer feed often proving to be more acceptable to the fish (Houlihan, 2001). The texture of feed depends on how feeds have been manufactured.
- Flavor and odor of feed are related to sensory attributes, but can be said in different names such as taste and smell. Smell and taste can affect the palatability of feed. Fresh feeds have an agreeable odor. High protein feeds have a strong odor of fish meal (which is made from fish,

squid, and shrimp). Spoiled feeds taste bitter, sour or rancid (Cruz, 1996). Therefore, it’s important to buy appropriate feed and store them properly in cool and dry stores.

Physical factors

- Size, shape and length of the feed made according to species and size of the fish. According to Bailey et al. (2003), the salmon farmers use many different sized of feed during the grow out period and each time size are changed new calculations per biomass of fish according to size of fish must be done. The large size of feed may affect the amount of feed during the feeding and may cause wastage if fish unable to catch up the feed before they sink to the bottom of the net or pond.
- Feed density: -The stability of feed also important the feed must maintain integrity and steady to water in order to do not degrade (Southgate, 2003). Water stability of feed is important, because the feed should remain in water until it is ingested (Gonzales and Allan, 2007).

2.4 FEEDING METHODS

Fish can be fed by hand, using automatic feeders, or by using demand feeders. According to (Graig and Helfrich, 2009) automatic feeders are made from belt feeders, which work on wind-up spring, or electric vibrating feeders, which can be programmed according the timetable of the feeding. Demand feeders do not require electric supply. Demand feeders allow fish to eat when they are hungry and when environmental conditions are optimum. Demand and automatic feeders save time, labor and money. Large fish farms use trucks to transport feed in order to thrown into ponds or it can be distributed by using machines such as air-blowers to reach considerable distances to feed fish (Southgate, 2003). There are several methods to feed fish (Table 3)

Table 3. Different feeding methods of fish.

Feeding methods	Description
Hand feeding	In hand feeding farmer has daily visual observation that, how the feed must distributed and monitors the activity and satiation of the fish (Alanärä et al., 2001).
Automatic feeding	The electro-automatic feeder has containers and feed distributing portion timbers which is controlled by a timer length of feeding and can be adjusted in order to feed the fish according to feed portion amount (Varabi, 1984).
Demand feeding	The demand feeders suspended above a fish tanks allowing to trigger the feed, release by striking to extend into water to dictate the timing of feed delivery which can minimize feed wastage, reduce the competition, overfeeding due to the portions are controlled (Jobling et al., 2001a, Coves et al. 2006, Southgate, 2003, Woynarovich et al., 2011).

2.4.1 Feeding tables

Currently the commercial feeding manufacturers have developed feeding tables for different fish species according to the size and age of the fish. Feeding tables take into account the size (weight) of the fish and the water temperature as well as daily feed allowance (Southgate, 2003). Appendix 1 has an example of a fish feeding table.

2.5 FEED CONVERSION RATION (FCR)

Feed conversion ratio is a feed efficiency calculation which gives the amount of feed which taken to grow one kilo of fish (Anderson and Silva, 2003).

The FCR can be calculated with the formula:

$$\text{FCR} = \frac{\textbf{mass of food consumed (dry)}}{\textbf{increase in mass of animal produced (wet)}}$$

FCR is used to determine or guide one on how to efficiently use feed. It is important for the nutritionist that allows for the estimation of how much feed is required for the growing cycle (Anderson and Silva, 2003).

2.6 SPECIFIC GROWTH RATE (SGR)

The specific growth rate (SGR) is the daily growth rate of fish body weight in percentage.

The SGR can be calculated in the formula:

$$SGR = \frac{\text{final weight (g)} - \text{initial weight(g)}}{time\ between\ weightings\ (days)} * 100$$

The rate of growth in fish depends on different factors such as species, age, water temperature, quality and quantity of food. Young fish are capable of doubling their weight in a much shorter time than when they are older due to fast growth rate. Therefore it is useful to know specific growth rate in different age of the fish.

2.7 CHALLENGES IN FEEDING OF FISH

Fish feeding is an important part of aquaculture that needs to be carried out responsibly. Overfeeding, insufficient feeding and fish diseases are some of the challenges faced when feeding fish.

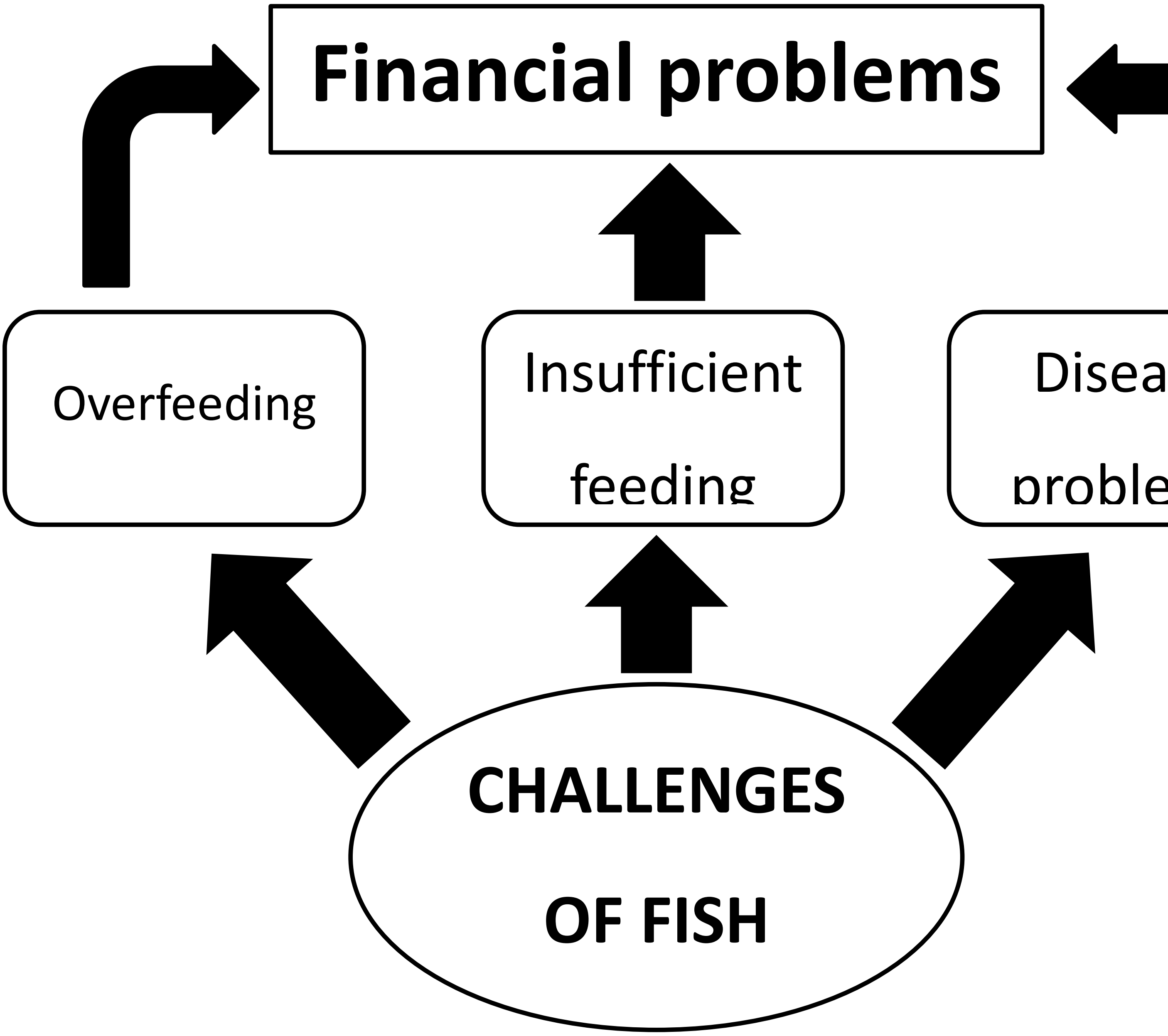

Figure 1. Challenges of feeding on fish farms and aquaculture.

- **Overfeeding**

One of the most important challenges in fish feeding is overfeeding (Fig.1). In intensive fish farming in coastal waters, a big amount of organic waste in the form of waste feed and fecal material is generated (Yokoyama et al., 2009). Overfeeding leads to losses of expensive feed, polluted water and water ecosystems, which can also lead to stress in fish and disease (Talbot et al., 1999).Overfeeding where fish receive more that they can consume, can be harmful to production and environmental sustainability of aquaculture. Furthermore, where overfeeding happens there will FCR more and where FCR is more but growth rate is less than it will lead loss of feed (Talbot et al., 1999).

In re-circulating aquaculture systems overfeeding can burden filtration systems and increase environmental degradation. One of the practical ways to solve these challenges is reducing organic waste. Choose appropriate and "low-pollution" feed, such as extruded pellets (Beverige, 1984). Furthermore, to avoid overfeeding there should be automatic feeding devices which can fix the time to give proper amount of feed.

- **Insufficient feeding**

Insufficient feeding increases competition between the fish reduces growth and decreases FCR (Yokoyama et al., 2009) (Fig.1). Obvious signs of insufficient feeding problems are increasing differences in individual sizes, growing aggressiveness and cannibalism. Lack of sufficient feed manifests itself in bitten/damaged fish and dead fish (Woynarovich et al., 2011).

- **Disease**

The problems of disease can occur during the incorrect calculation of feed ratio, which brings to depletion and overfeeding of fish. Due to depletion fish can deteriorate, and get some sickness. Poor-quality feeds can also cause problems of disease. Poor storage methods can result in spoilage from moulds for instance the red toxic fungi trichothecene, which has been identified in feed (Rahkonen et al., 2003) (Fig.1).

In the last overfeeding and other problems will lead financial problems of fish farms (Fig.1). Not following the feeding instruction will lead to overfeeding and feed wastages. Some fish will eat feed over than they have and there will deposition of fat in abdominal cavity. To fish farmer it is irrelevant because during the gutting they have to remove fat and fat are removed it means the feed are wasted.

The quality of feed is an important issue in fish feeding. The feed in fish farms must be stored in cool, dry places such as warehouse or storage room and never feed wet and moldy. Heat and moisture also decrease feed quality and can be cause of contamination by microorganisms. Therefore according to Masser and Cline (1990), caged fish should never be fed commercially packaged diets older than 60 days past the manufacturing date.

The size of the fish feed vary for different fish species and according to the age of the fish. Feeding with too small sized pellets can result in insufficient feeding because more energy is needed to locate the pellets and eating more of them to satisfy the fish needs. On the other hand, feeding with too large sized pellets can decrease feeding and in extreme cases, even cause choking (Graig and Helfrich, 2009).

3. OBJECTIVES

The main purpose of this experiment was to determine the effect of the level of feeding on the growth parameters of rainbow trout fingerlings.

More specifically, the main objectives of this experiment were to:

- To determine the effect of upkeep feeding (minimum feeding group) on the weight and length gain of rainbow trout fingerlings,
- To determine the effect of upkeep feeding(minimum feeding group) on the feed conversation ratio of rainbow trout fingerlings
- To determine the effect of feeding up to satiation (optimum feeding group) on the weight and length gain of rainbow trout fingerlings ,
- To determine the effect of feeding up to satiation (optimum feeding group) on the feed conversation ratio of rainbow trout fingerlings.

This experiment can be used to demonstrate the differences between feeding practices and determine good feeding practices in aquaculture activities.

4. MATERIALS AND METHODS

4.1 MATERIALS

4.1.1 Fish and fish tanks

The total number of fingerlings was 180 and they were divided in to 6 tanks with 30 fish each. The initial size of fingerlings was approximately 20-25g by weight and 12-13cm by length. The fingerlings were brought from a private fish farm Savon-Taimen Ltd. located in Rautalampi, Finland. All the rainbow trout fingerlings were placed in fiberglass tanks, each with a water volume of 45 liters- Oxygen levels in each tank were measured using oxygen sensors.

4.1.2 Feed and Feeding equipments

The fish feed used was 2mm Inicio Plus produced by the company Bio Mar. During the experiment, automatic feeding belts were used to distribute feed. Feeding belts were assembled at each tank and this functioned using electricity. The feeding time was set to 8 hours per day for each belt. The feeding belts functioned from 12:00 pm till to 8.00 am daily.

In this experiment two main feeding methods was used, the optimal feeding and upkeep feeding.

Optimal feeding is feeding with automatic feeding belts, in addition by hand until satiation. The purpose of optimal feeding is to get optimal development of fish body weight and lenght.

Upkeep feeding is feeding with automatic feeding belts. Usually automatic feeding devces working with electrocity and has timer which can ajusted to different time to feed the fish . Generally automatic feeding belt adjusted to feed according to feeding tables which given by commercial feeding instructions

4.2. EXPERIMENTAL SET-UP

4.2.1 Feeding groups and feeding procedure

The feeding experiment lasted six weeks during the summer 2010. Fish were divided into two groups, each with three tanks. The two groups were fed on different levels and will be henceforth referred to as the minimum and optimum feeding groups.

The minimum feeding group was fed using automatic feeding belts, seven days a week continuously. The group was fed according to 60% of the amount of indicated on the Biomar feeding guideline.

The optimum feeding group was fed, by belt 7 days a week and also by hand up to satiation. This group received feed in the amounts of 70% of the Biomar feeding guideline. Pellets were weighed in disposable plastic containers and then put on the belt feeders for both feeding groups.

4.2.2 Maintenance of water temperature

The Fish Research Unit water supply came from Lake Kallavesi, Neulalahti bay through two pipes: one coming from a depth of 18 meters and the other, 6 meters. The temperature of the water from the first pipe was colder that from the second pipe in order to maintain an appropriate water temperature for fish. Water from the two pipes was mixed in a proper ratio prior pumping the water into tanks, in order to achieve the desired water temperature. The temperature of water in tanks was approximately 12-13°C. In the fish tanks, the water flow was set at 8 liters per minute, by pumping water from the tank into 1 liter jars. The fish tanks were cleaned manually.

4.2.3 Anaesthetization and measuring the biomass of fish

First, rainbow trout fingerlings were moved from tanks, using nets and carried in buckets to the measurement site.

The bucket intended for anaesthetization was filled with water and anaesthetization solution is prepared using MS-222 (100mg/1liter) and $NaHCO_3$ (100mg/1liter).

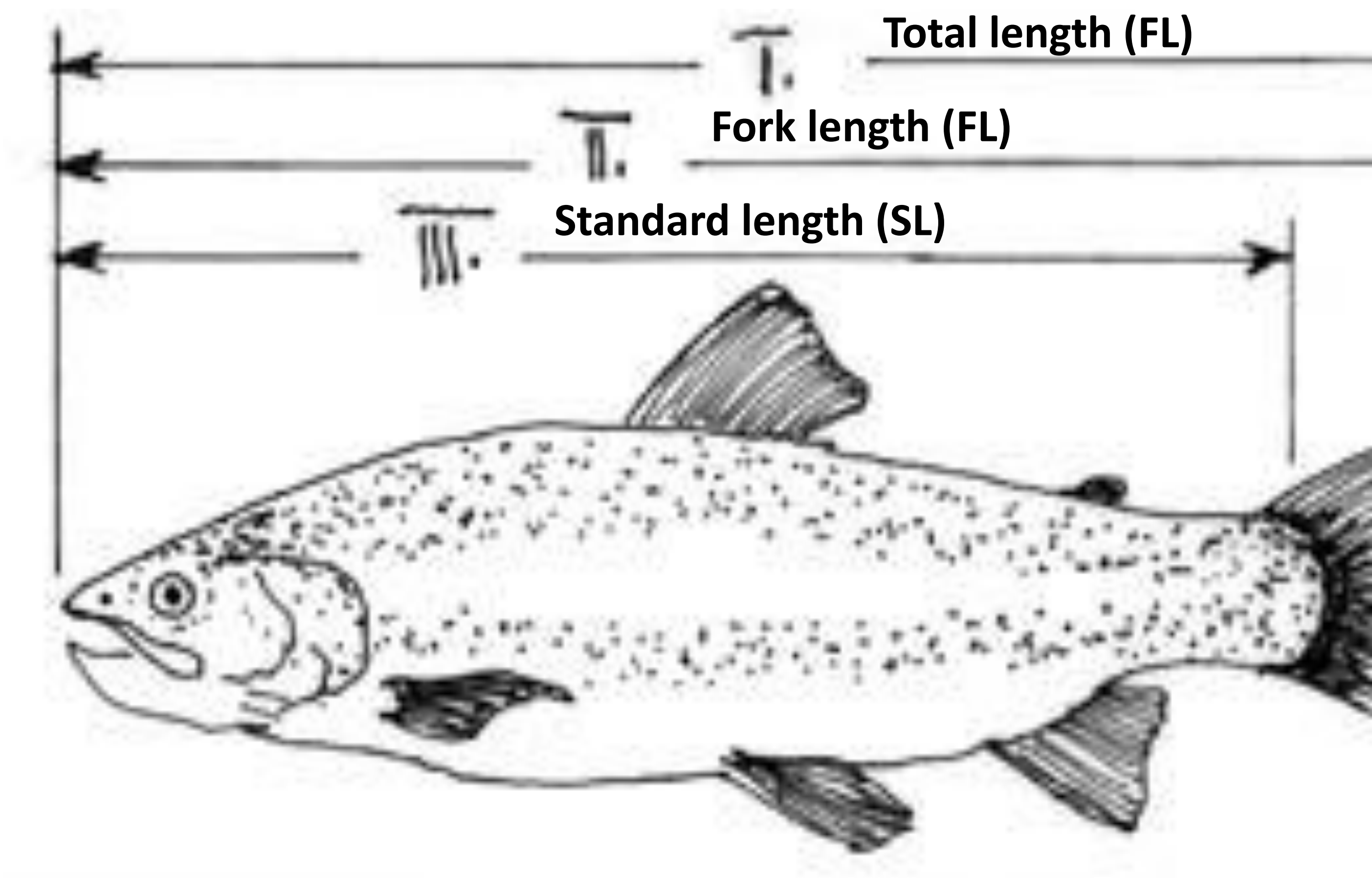

Figure 2. The standard measurements of body parts of a rainbow trout (Woynarovich et al., 2011).

After the fish was sedated, the maximum total length was measured. The total length is defined as the length from the anterior-most part of the fish to the tip of the longest caudal fin rays and is measured when the lobes of the caudal fin are compressed (Fig.2) (Woynarovich et al., 2011).

In addition the body weight was measured using scales. A wet paper towel was placed on the scale to avoid drying of the fish and making them susceptible to bacterial contamination. All the measurements were taken, gently and accurately and recorded in a data sheet (Appendix 2).

The weight and length of the fish was measured four times during the whole experiment; in the beginning of the experiment, two times mid-way of the experiment and finally once at the end of the experiment. In the middle of the experiment the weight of fish have been measured in groups, to know the biomass. Therefore, the lengths of the fish were not measured but in the beginning and in the end the length of fingerlings measured individually.

After measurements were taken, fish were placed into another bucket until recovery and followed by return to their tanks.

4.3 STATISTICAL ANALYSIS

The average weights of rainbow trout fingerlings were analyzed to compare differences between the minimum and optimum feeding groups using analysis of variance (ANOVA).

The average lengths of rainbow trout fingerlings were analyzed to compare differences between the minimum and optimum feeding groups using analysis of variance (ANOVA).

Differences in feed conversion ratio (FCR) between the minimum and optimum feeding groups and specific group rate (SGR) were analyzed using the Mann Whitney U test. All statistical tests were performed at the 95% confidence level using IBM SPSS 19.0 software.

5. RESULTS

5.1 Weight and length measurements

The average weight measurement values of rainbow trout fingerlings (*O. mykiss)* in optimum and minimum feeding groups were compared as time function (Figure 3.) After the 6 weeks feeding trial the average weight of fish increased in both groups but weight values in the optimum feeding group increased more. There were significant differences in the average weight between minimum and optimum feeding groups after 2 weeks of feeding (p=0,003, ANOVA), after 4 weeks of feeding (p=0,002, ANOVA) and after 6 weeks of feeding (p=0.000, ANOVA). After 2, 4 and 6 weeks of feeding, the optimum feeding group was significantly heavier than the minimum feeding group.

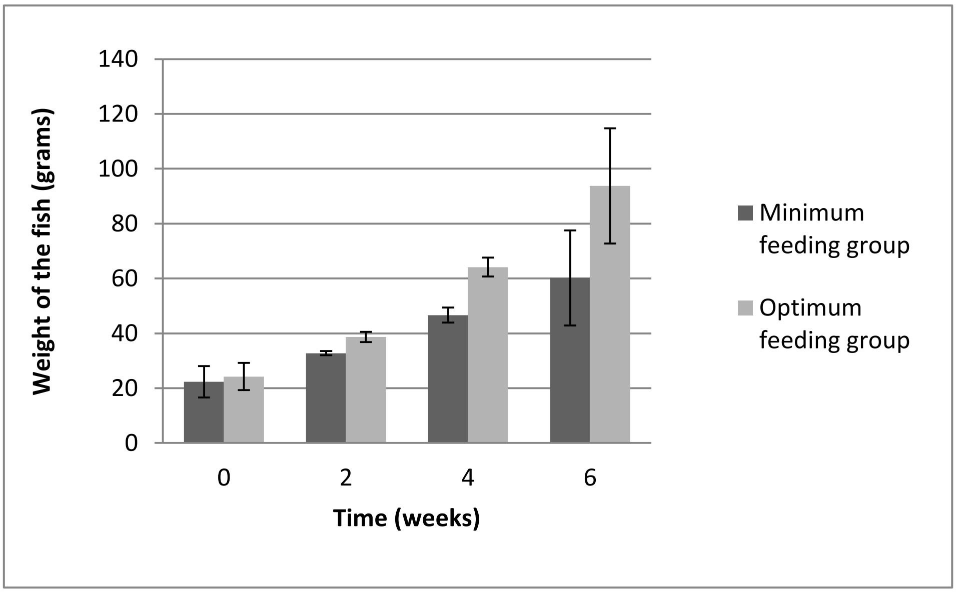

Figure 3. The average weight (g±SD) of rainbow trout fingerlings *(O.mykiss)* in minimum and optimum feeding groups over six weeks of feeding.

Average length measurements of rainbow trout fingerlings *(O.mykiss)* in optimum and minimum feeding groups were compared as a time function (Figure 4). The average length of fish increased during the experiment. There were significant differences in average length, between minimum and optimum feeding groups over 6 weeks of feeding (p=0.000, ANOVA). After 6 week feeding trial the optimum feeding group was longer than minimum feeding group

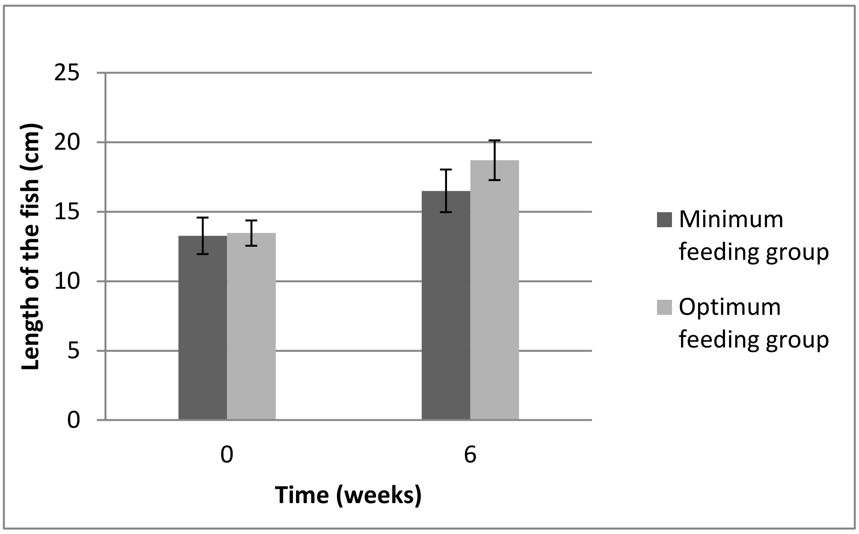

Figure 4. The average length (cm±SD) of rainbow trout fingerlings *(O.mykiss)* in minimum and optimum feeding groups over six weeks of feeding.

5.2 Feed conversion ratio (FCR)

The feed conversion ratio (FCR) for the minimum and optimum feeding groups of rainbow trout fingerlings after a 6 week feeding experiment was compared (Figure. 5). The FCR of the optimum feeding group was slightly higher than FCR of minimum feeding group. There were no significant differences in FCR between the minimum and optimum feeding groups (p=1.000, Mann-Whitney U test).

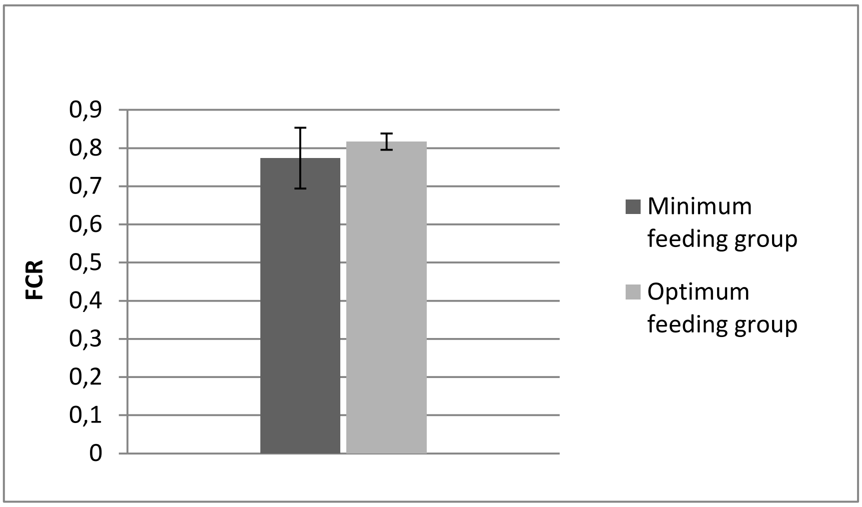

Figure 5. The feed conversion ratio (FCR±SD) of rainbow trout fingerlings *(O.mykiss)* after 6 weeks of feeding

5.3 Specific growth rate (SGR)

Specific growth rate (SGR) for minimum and optimum feeding groups of rainbow trout fingerlings after 6 weeks of feeding were compared (Figure 6). SGR in the optimum feeding group 0.96% was higher than minimum feeding group during the feeding per day. However, there were no significant differences in SGR between minimum and optimum feeding groups (p=0.100, Mann-Whitney U test).

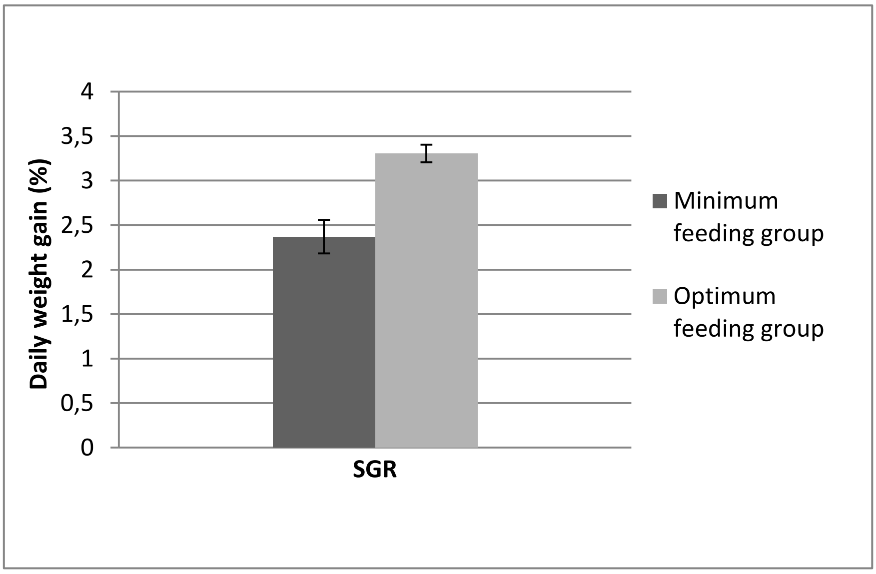

Figure 6. The specific growth rate (%±SD) of rainbow trout fingerlings *(O.mykiss)* after 6 weeks of feeding.

After 6 week feeding trial from each tank the 5 fingerlings opened. In some fingerling has been found fat deposition in abdominal cavity.

6. DISCUSSION

Managing fish nutrition is important for fish farmers to achieve acceptable quality and size level required by fish processing companies as well as customers. The advantages of hard work by fish farmers in feeding fish appropriately and following feed companies instructions will lead to progressive improvement in quality of fish and to reach optimal body weight and length of fish.

As feed constitutes ~ 40-50% of the fish production costs, attention should paid to feed consumption, feed distribution, feeding behavior, waste level and feed ingestion (Purser and Forteath, 2003).

This experiment aimed to evaluate the physical changes of rainbow trout fingerlings over six weeks of feeding between minimum (60% of Biomars recommendation from the belt feeding) and optimum (70% of Biomars recommendation from the belt feeding and fed up to satiation) feeding levels.

The weight of rainbow trout fingerlings in this experiment significantly increased during six week feeding trial. In this feeding period, the average of weight of fish increased for optimum feeding group more than minimum feeding group. Clearly, the optimum feeding group, the fish were fed until satiation by hand, therefore the weight of fish is increased more in comparison with the minimum feeding group.

Furthermore, the length of the rainbow trout fingerlings also grew more in optimum feeding group than in the minimum feeding group, after the six week feeding trial. Here, also can be seen the fish in optimum feeding group were significantly longer than minimum feeding group.

However, the weight and length of some fingerlings in optimum feeding group was similar to minimum feeding group even smaller. There can be several reasons why some fingerlings growth faster than others. Competition for feed is usually occurs under the condition of restricted supply in terms of quantity and space of the fish. The density of the fish inside the tank or pond can be direct reason of fish competition (Kestemont and Baras, 2001). However, in our experiment the density was not so high because there were 0.53kg fish/m^3 of water in tank in the beginning of the experiment and 2.08kg fish/m^3 of water in the end of the experiment.

Holm et al. (1990), evaluate the interaction between density and food availability of rainbow trout, where the 134 tagged and untagged fish reared 5 month in 1m^2 tanks used with 0.2 m water depth. During the trial fish fed hourly and fish fed sufficiently but growth rate was lower than expected. In the end of the experiment the mortality was 13% and density was higher. Food availability had a significant interaction effect on growth between food availability and fish density. In higher density of fish, higher feeding regimes could compensate but even making feed availability continuously did not compensate for density-linked growth depression.

The cannibalism is the main sign of stress in during the feeding of rainbow trout due to increase of different size of fish which leads to aggressiveness and cannibalism. To avoid this problem there should be grading of growing fish (Woynarovich et al, 2011). There was no cannibalism during the experiment among the fingerlings.

Social environment may be influenced not only by population density, but also by size heterogeneity (the quality or state of being) and sex ratio (Toguyeni et al., 1996). According to Jonsson and Akerman. (1998), intersexual aggression differences between juvenile rainbow trout suggest that male juveniles are more aggressive than females and more aggressive fish has more access to food. In our experiment there was no identification of male and female fingerlings between the groups during the experiment, therefore we can only suppose that, it can be one of the reasons why some fingerlings growth faster than others in optimum feeding group.

After six week feeding trial in optimum feeding group, some fingerlings were found to have fat deposition in abdominal cavity. The main reason is assumed to be the consumption more feed and getting extra energy by fingerlings. The extra energy which they gained was deposited as fat.

Another reason could be the amount of lipids in the feed which was given to fingerlings, but all fish were fed using similar feeds intended for fingerlings during the trial. Another explanation is the size of fish. If the fingerlings which had extra fat were big, the issue may be related to social dominance. Dominant fish get most food and extra energy is stored as fat in abdominal cavity According to Kiessling et al. (1991), the total fat content increases with an increase in the size of fish. In a stable environment, it is a direct effect of feed ratio level and age.

Fat deposition in fish is not desirable for the fish farmer, especially when fish reach marketable size. Fish farmers should fulfill the requirements of fish processing factories to sell their products, and mostly fish processing factories prefer to get fish without fat or with less amount of fat composition.

Fat deposition also causes extra work because during gutting farmers should remove the fat deposition in abdominal cavity together with intestines. Fat deposition implies increased feed consumption which in turn has economical consequences for the fish farmer. Therefore, fish farmers should follow the feed instructions which are given by feed companies. The modern fish feed formulations vary according to the size and life stage of the fish. The juvenile feed contains more protein while adult fish needs more energy to upkeep metabolism. This upkeep energy is cheaper to produce with additional fat than with protein.

The majority of customers prefer flesh fillet without fat in fish. It is also depends of fish processing factories what type of fish products they will produce from fish. However, the fat deposition of fish during the feeding is not desirable result for farmer and for fish processor also.

The feed conversion ratio (FCR) in the minimum feeding group was lower than in the optimum feeding group. Slightly higher differences were seen in the optimum feeding group due to fingerlings fed by hand until satiation in addition with automatic feeding belts. FCR for fingerlings after six feeding was around 0.8 for both group and there were no significant differences between the groups.

Suzuki et al. (2008), compared effect of self-feeding and hand-feeding on the growth, FCR and damage of fins (dorsal and caudal) of rainbow trout (*O.mykiss*). In this experiment the juvenile rainbow trout initial weight was 60-70 grams. The results of (Suzuki et al., 2008) article on the growth rate in self-feeding was significantly higher and 30% of feed consume more than hand feeding. In our experiment the growth rate was higher in optimum feeding group.

Furthermore, Bailey and Alanärä (2006) show that there is no significant correlation between portion size and FCR. Similarly, in our experiment there were no significant differences in FCR for juvenile rainbow trout held at temperature 13°C.

In our experiment the body weight and length of the fish in optimum feeding group grew significantly more than in the minimum feeding group with the cost of disadvantages like fat accumulation and size heterogeneity (which was also found from minimum feeding group).

The important issue brought out in this experiment is the importance of following feeding instructions given by feed companies and with the proper amount of feed and content. Following and maintaining the feeding instructions results in the avoidance of overfeeding, insufficient feeding, disease problems, feed waste and other disorders.

Farmers should control the temperature of water to avoid slackness and too much activity of the fish, because when temperature is high fish will be too active and eat more which results in fat deposition or disease problems but when temperature is low the fish are slack and feed demand is slow which results in insufficient feeding and starvation. According to Woynarovich et al. (2011), for rainbow trout fingerlings, length of 12.5 cm and to an average body weight of 25 g, the water temperature should be between 5°C and 15°C. In water temperature around 7-18°C the appetite of rainbow trout is optimal. At lower or higher temperature of water fish loose appetite.

The feeding devices or automatic feeding belts should work properly to maintain time and portion of the feed. Hand feeding should be carried out carefully, because human disturbance can cause stress in fish.

7. CONCLUSION

The main objectives of this thesis was to determine the physical changes, particularly the weight and length changes of juvenile rainbow trout in two different feeding groups minimum and optimum in six week feeding trial.

A lower FCR than expected means that fish are being insufficiently fed and thus can lose out on energy for growing or even for surviving. If the FCR is higher than the optimum level it means the feed is being wasted.

Fish should be sorted according to size to avoid competition and dominancy issues during the feeding.

It is important to feed fish with proper feed containing the required nutrients, follow feeding instructions, feed fish with a proper amount of feed and to choose a proper method of feeding to get optimal results in the development of the body weight and length of the fish.

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APPENDIX 1.

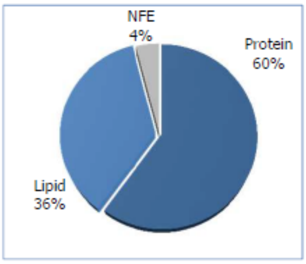
Inicio plus

21/8/2013

INICIO Plus Trout

Declaration		0.5 mm	0.8 mm	1.1 mm	1.5 mm	2 mm
Crude protein	%	58	56	56	54	52
Crude lipid	%	15	18	18	22.0	23
Carbohydrates (NFE)	%	10	9	9	8.8	11
Fibre	%	0.2	0.3	0.3	0.4	0.4
Ash	%	11.4	10.9	10.5	10.0	8.7
Total phosphorus (P)	%	1.7	1.6	1.6	1.5	1.3
Gross energy	MJ/kg	21.3	21.8	22.0	22.8	23.4
Digestible energy	MJ/kg	18.8	19.2	19.3	19.8	20.5

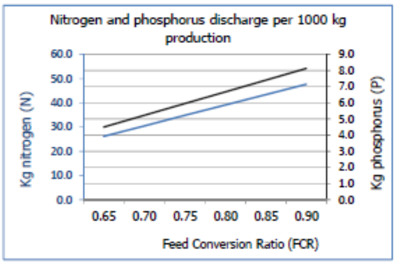
Energy distribution



Composition

Fish meal
Fish oil
Wheat gluten
Wheat
Pea proteins
Krill meal
Soya concentrate
Probiotics
Vitamins and Minerals

Ecological value



Due to natural variations in the raw materials, the information about carbohydrates, fibre, and ash, and the composition may vary compared to the stated values. See label for further information.

The information on energy distribution, composition and ecological values applies to 1.5 mm

Feeding guides (kg feed per 100 kg fish per day)
Lowest possible feed conversion rate – to be used when optimal feed utilisation is required

Fish size		Pellet size										
gram	cm	mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
0.2 - 0.4	3 - 4	0.5	1.54	1.82	2.12	2.45	2.78	3.09	3.33	3.43	3.31	2.78
0.4 - 1.5	4 - 5	0.8	1.37	1.62	1.90	2.19	2.49	2.77	2.99	3.08	2.97	2.49
1.5 - 5	5 - 8	1.1	1.20	1.42	1.66	1.92	2.18	2.43	2.62	2.71	2.60	2.18
5 - 15	8 - 11	1.5	1.01	1.19	1.40	1.62	1.84	2.05	2.21	2.28	2.19	1.84
15 - 50	11 - 16	2	0.83	0.98	1.15	1.33	1.52	1.69	1.82	1.88	1.81	1.51

Optimal feeding – to be used when an optimal relation between large production and good feed utilisation is required

Fish size		Pellet size										
gram	cm	mm	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C
0.2 - 0.4	3 - 4	0.5	1.37	1.88	2.53	3.36	4.35	5.46	6.53	7.24	6.87	3.79
0.4 - 1.5	4 - 5	0.8	1.20	1.64	2.22	2.95	3.84	4.83	5.81	6.46	6.12	3.33
1.5 - 5	5 - 8	1.1	1.02	1.40	1.90	2.53	3.30	4.17	5.03	5.61	5.31	2.86
5 - 15	8 - 11	1.5	0.84	1.15	1.56	2.09	2.73	3.46	4.18	4.66	4.41	2.36
15 - 50	11 - 16	2	0.67	0.93	1.26	1.68	2.20	2.80	3.39	3.78	3.58	1.91

Feeding should be adapted to the chosen production strategy and current farming conditions.
Recommended storage of feed is in dry and cool place, protected from direct sunlight and pests.

(0.84 - 1.3)

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APPENDIX 2.

Tank 3	MINIMUM									
date	weight	number of fish	growth rate	scaling	FCR	Feeding from belt	Feeding by hand	Dead	Notes	Feed to the belt
27.5.2010	**22,3**	**30**	3,2	1,3	1	21,2				12,7
28.5.2010	23,0	**30**	3,1	1,3	1	21,7				13,0
29.5.2010	23,7	**30**	3,1	1,3	1	22,2				13,3
30.5.2010	24,5	**30**	3,1	1,3	1	22,7				13,6
31.5.2010	25,2	**30**	3,1	1,3	1	23,2				13,9
1.6.2010	26,0	**30**	3,0	1,3	1	23,7				14,2
2.6.2010	26,8	**30**	3,0	1,3	1	24,2				14,5
3.6.2010	27,6	**30**	3,0	1,3	1	24,7				14,8
4.6.2010	28,4	**30**	3,0	1,3	1	25,2				15,1
5.6.2010	29,3	**30**	2,9	1,3	1	25,7				15,4
6.6.2010	30,1	**30**	2,9	1,3	1	26,2				15,7
7.6.2010	31,0	**30**	2,9	1,3	1	26,7				16,0
8.6.2010	31,9	**30**	2,9	1,3	1	27,3				16,4
9.6.2010	32,8	**30**	2,8	1,3	1	27,8				16,7

Tank 4	OPTIMUM									
date	weight	number of fish	growth rate	scaling	FCR	Feeding from belt	Feeding by hand	Dead	Notes	
27.5.2010	**22,9**	**30**	3,2	1,3	1	21,6				15,2
28.5.2010	23,6	**30**	3,1	1,3	1	22,1	14,3			15,5
29.5.2010	24,4	**30**	3,1	1,3	1	22,6				15,8
30.5.2010	25,1	**30**	3,1	1,3	1	23,1				16,2
31.5.2010	25,9	**30**	3,0	1,3	1	23,6	[illegible]			16,5
1.6.2010	26,7	**30**	3,0	1,3	1	24,1	[illegible]			16,9
2.6.2010	27,5	**30**	3,0	1,3	1	24,6	5,5			17,2
3.6.2010	28,3	**30**	3,0	1,3	1	25,1	9,8.			17,6
4.6.2010	29,1	**30**	2,9	1,3	1	25,6	12,6			17,9
5.6.2010	30,0	**30**	2,9	1,3	1	26,1				18,3
6.6.2010	30,9	**30**	2,9	1,3	1	26,7				18,7
7.6.2010	31,7	**30**	2,9	1,3	1	27,2	37,0			19,0
8.6.2010	32,6	**30**	2,8	1,3	1	27,7	5			19,4
9.6.2010	33,6	**30**	2,8	1,3	1	28,3				19,8
							99.			
							104,2.			

89,2

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