Appendix 1. – Thesis topic application form

APPLICATION OF BEEKEEPING BY-PRODUCT (SLUM GUM) IN FISH FEED

APPLICATION FORM

Filled by the student

Student Name: NGUYEN KIM NGAN Neptun ID: JOHJIV

Course: Animal Nutrition and Feed Safety master program in English

Level of Education: MA Grade: Master

Specialisation: Farm Animal Nutrition

Student e-mail address: ngankinn@gmail.com

Name of Host Institute / Department:
Institute of Aquaculture and Environmental Safety

Primary supervisor name and position: Dr. Kucska Balázs, Senior Research Fellow, Institute of Aquaculture and Environmental Safety, Department of Applied Fish Biology.

Independent Consultant name, position, workplace:

Thesis topic:
Application of beekeeping by-product (slum gum) in fish feed

Date: ____2023____________ year ______05_________ month __02_____ day

Kucska Balázs ______________ Ngân

Primary supervisor Independent consultant Student

Filled by the host course leader/coordinator and the Head of host institute/department!

Application for the thesis topic is accepted
Date: ___2023________year ____05________ month ____02___ date

____
Course leader/coordinator

Student and thesis topic is admitted by the Institute
Date: ___2023________year ______05______ month ____02___ day

____
Head of Institute/Department

Appendix 2

THESIS

NGUYEN KIM NGAN
Animal Nutrition and Feed Safety

Kaposvár
2023

Appendix 3

Hungarian University of Agriculture and Life Sciences

Kaposvár Campus

Animal Nutrition and Feed Safety

APPLICATION OF BEEKEEPING BY-PRODUCT (SLUM GUM) IN FISH FEED

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Kaposvár

2023

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1. Introduction

In 2019, the global consumption of fish and other seafood attained an all-time high of over twenty kilograms per person, reported by the Food and Agriculture Organization of the United Nations (FAO). That record consumption underscores the demand for fish and other seafood as a vital resource for nutrition and food security. The considerable aquaculture production worldwide originates from East Asia and the Pacific regions. According to Evans (2020), China alone generated roughly sixty-six million tonnes of aquaculture production in 2018. In contrast, the price is increasing by the high demand for fish production, which uses feed in aquaculture production. So, that has led to the search for more sustainable and cheaper alternative protein sources, such as insect meal (Ebertz 2019). The high demand for fish also has led to the increasing price of fishmeal, a key ingredient in aquaculture feed, resulting in higher feed costs. Furthermore, a significant percentage of fish from marine is used for fishmeal and fish oil production rather than human consumption, posing concerns. Thus, the replacement solution would reduce the reliance on fish feed, find cheaper, but also more sustainable alternative protein sources to improve the profitability, and sustainability of aquaculture (Richter 2022).

In this context, insect meal has emerged as a potential option for changing from feedstuff in aquaculture. Insects can be a sustainable source of protein, such as products on organic waste substrates and by-products, requiring minimal energy and water, leaving a small ecological footprint, and having a limited need for arable land compared to vegetable substitutes like soymeal (Le Feon et al., 2019). In some studies by Marono and the team, by-products from insects were rich in essential amino acids, which made them more nutritiously valuable feed ingredients for aquatic animals (Marona et al. 2015).

Apiculture plays a critical role in sustaining agriculture and the environment. The process of pollination, facilitated by honey bees, ensures successful plant reproduction and crop production. On the other hand, beekeeping significantly contributes to the development of rural areas by providing additional sources of income for farmers and creating employment opportunities. In addition, the diverse range of bee products, with their various nutritional, medicinal, and cosmetic properties, highlights the importance of bees to human well-being.

Beekeeping is an extensive practice throughout the EU, with diverse production conditions, yields, and executions. While China is the world's largest honey producer, the EU is the second largest, primarily in southern Europe, where climatic conditions are more conducive to beekeeping. These countries include Romania, Spain, Hungary, Germany, Italy, Greece, France, and Poland. As of 2021, there were approximately 612,000 beekeepers and 18 million hives in the European Union. These hives produce around 280,000 tons of honey annually, known as other bee products such as beeswax, pollen, royal jelly, and propolis. Their nutritional, medicinal, and cosmetic properties showed more potential value for human health. Globally, honeybees' products appeared as complementary medicines, especially in Oriental countries. Those products are classified into three categories: bee collection and brewing products, such as propolis, honey, pollen, and bee bread; bee secretions, including royal jelly and beeswax; and ecological bodies and hives, such as bee larvae, bee corpses, and old beehives (Luo et al. 2021). The use of hive products and apitherapy dates back to ancient times and was implemented in phytotherapy and diet for their potent therapeutic characteristics.

Honey production is a valuable industry, and the extraction of beeswax from honeycombs is an important process that yields a valuable by-product. In contrast, the efficiency of beeswax extraction can vary depending on various factors. The research of Kole (2022), investigated the efficiency of beeswax extraction from honeycombs and optimized the extraction conditions to achieve maximum efficiency. Slum gum, as known as a byproduct of beekeeping has been used in various factors such as feed industries, fertilizer, or biodiesel additives (Hariram and Bharathwaaj, 2016). During the filtering stage, the wax is stripped of all the impurities that accompany it, which cannot pass through the sieve, known as “slumgum”, which is a dark-colored residue (Lind et al. 2007). Slum gum has also been identified as a potential feed ingredient for fish, particularly tilapia (*Oreochromis niloticus*), which is a widely cultivated species in aquaculture. Bee’s slum has been shown to be a good source of nutrients for crops, particularly in terms of nitrogen and phosphorus (Morales-Corts et al. 2014). Slum gum has a high nitrogen content, which can contribute to the growth of crops. In addition, green waste and insect by-products have been found to improve soil physical properties, such as water-holding capacity and aggregate stability (Ali et al. 2007). These properties can enhance soil fertility and promote plant growth. In addition to its protein and fat content, slum gum is also a good source of dietary fiber, which has numerous health benefits for fish. Fiber in slum gum help to decline cholesterol levels, promote satiety, or lower blood sugar levels, which can aid in weight management (Gachumi 2015). Moreover, slum gum shows some advantages, such as antimicrobial, antioxidant (Morales-Corts et al. 2010), and anti-inflammatory properties (Khalil et al. 2019). Recent studies have shown that slum gum contains approximately 18,87% crude protein and 11.8% crude fiber, making it a valuable source of energy and nutrients for feedstuff (Babarinde et al. 2013). Besides, bee products are used in poultry feed in various forms, such as propolis, and bee pollen, and by-products, such as slum gum, which has been used in various industries and has potential as a feed ingredient. The appropriate dosage of these products in farm animal feed was found to positively influence the performance of broiler chickens, with lower volume having a significant growth-promoting effect (Babarinde et al. 2011). These bioactive compounds can have potential benefits for animal health, including fish health. In particular, honey bee products have been found to improve the growth performance and disease resistance of farm animals, and fish, such as Nile tilapia (*O. niloticus*) (Amel et al. 2014).

Nile tilapia was chosen as the subject of this experiment due to its favorable characteristics for aquaculture production. Tilapia is known for its ability to tolerate high planting densities, resistance to diseases, and adaptability to various water qualities. Additionally, Nile tilapia has good growth potential. It is popular among consumers due to its taste, low-fat content, and easy consumption. Furthermore, tilapia has excellent meat quality, making it economically significant for food production. In light of these considerations, it is important to explore ways to enhance the efficient and sustainable production of Nile tilapia.

Therefore, this experiment aims to provide valuable insights into the effects of slum gum supplementation on the growth rate of Nile tilapia, which could contribute to the development of sustainable and economically viable aquaculture practices. Understanding the impact of slum gum supplementation on Nile tilapia growth could have implications for improving the efficiency and sustainability of food production in the aquaculture industry, considering the increasing demand for fish farms and the economic significance of its production.

The primary objective of this study assess the potential effects of slum gum supplementation on the growth performance of Nile tilapia. The specific target of the experiment is to determine the impact of replacing 10% and 30% of slum gum in the tilapia feed on the growth rate, survival rate, and feed conversion ratio of Nile tilapia. Besides, this trial aims to evaluate the potential benefits of using by-products in tilapia feed and to test the hypothesis that incorporating slum gum in the feed fish will have a positive effect on the growth rate of Nile tilapia. Consequently, the degree of this impact will be influenced by the level of supplementation, indicating that a higher concentration of slum gum may result in growth rates. In the main, this investigation has significant implications for the aquaculture industry as it explores the potential use of by-products to enhance the growth performance of commercially valuable fish species.

2. Literature

2.1 Apiculture

Apiculture involves the management of honey bee colonies with the aim of harvesting a variety of valuable products such as honey, beeswax, propolis, royal jelly, and more (Topal et al. 2021). Recent years have seen a surge in scientific research focused on unraveling the intricate biology and behavior of honey bees, as well as elucidating the role of these fascinating creatures in agriculture. The complex life cycle of a bee hive, as described by deGrandi-Hoffman in 1989, entails a division of labor among different types of bees, including the queen, workers, and drones. The queen bee serves as the reproductive powerhouse of the colony, laying eggs and perpetuating the population. The diligent worker bees, on the other hand, shoulder the responsibilities of nurturing the young and undertaking various tasks within the hive, while the drones, male bees with a singular purpose, exist solely for mating with the queen. Honey bees undergo a metamorphic journey, progressing through distinct stages of egg, larva, pupa, and finally emerging as fully developed adult bees. In addition to the intriguing dynamics of the bee colony, the honey and other products harvested from beekeeping operations have captivated the attention of researchers. These products are not only prized for their sensory delights and culinary applications, but they also show their medicinal properties and potential applications in various industries. Harvesting honey is a critical aspect of beekeeping, and there are different methods and equipment used for those purposes. In Yueyang Hu's research (2023) has explored various techniques for extracting honey from the comb, including centrifugation, crushing and straining, and even chemical methods. Timing the harvest of honey is essential in order to ensure that the bees have enough stores for the winter months and to avoid damaging the hive. In the notes of Sakagami in 1968, honey was usually harvested in late summer, or early fall, when the bees had stored adequate amounts for their own use. The honeycomb is often cut or scraped off of the frames and the honey is extracted using centrifugal force. In those cases, the products of honey could be harvested from a bee hive, including beeswax, pollen, royal jelly, and propolis.

Bee products, such as honey and beeswax, have a variety of functions and benefits for agriculture, including as a food source for humans and animals, as well as for medicinal and cosmetic purposes. Honey has been found to have antibacterial and antioxidant properties, and

may also have anti-inflammatory effects. Beeswax can be used in a variety of products, including candles and cosmetics (Al-Waili 2004).
In addition to their benefits for agriculture, bee products can also be used as a food source for farm animals, including in aquaculture. In 2020, Valentina Panettieri and her team explored the potential for bee products, such as pollen and honey, to be used as a feed supplement for fish and other aquatic animals. Some studies of them have found that incorporating bee products into fish feed can improve growth rates and stress.
After harvesting, there are also wasted products from beekeeping, such as beeswax and propolis. The potential uses for these waste products, include as an additive in animal feed and as a natural preservative in food products (Francesca Giampieri et al. 2017).
Overall, scientific research related to beekeeping has explored various aspects of hive management, harvesting techniques, and the benefits of bee products for agriculture, farm animals, and aquariums. These findings can inform best practices for beekeeping and highlight the importance of preserving bee populations for the health and sustainability of our food systems.

2.2 Econoical importance of Apiculture

In addition to their benefits for agriculture, bee products can also be used as a food source for farm animals, including in aquaculture. In 2020, Valentina Panettieri and her team explored the potential for bee products, such as pollen and honey, to be used as a feed supplement for fish and other aquatic animals (Panettieri et al. 2020). Some studies of them have found that incorporating bee products into fish feed can improve growth rates and stress.
Beekeeping is a widespread practice throughout all countries of the European Union. Romania, Spain, Germany, Hungary, Italy, Poland, France, and Greece are the main honey-producing countries in this region. Beekeeping plays a crucial role in rural development that is ingrained within rural communities. As of 2020, approximately 10 million hives are managed by beekeepers, who earn a significant portion of their income from beekeeping. These colonies of paramount are importance from an economic, environmental, and cultural perspective, contributing significantly to the social fabric of the regions in their location.
Beekeeping is an eco-friendly practice that operates in harmony with the natural habitat ecosystem. It provides an essential pollination service that works in synergy with wild pollinators, thereby contributing significantly to European agriculture, horticulture, and biodiversity. Between 2010 and 2015, honey prices on the international market continued to

rise, for example, Mexican and Argentinean honey prices reached as high as nearly 3,400USD/ton, and sometimes even up to 4,000USD/ton. As a result, the general value of European honey imports increased by 11%. Germany and the United Kingdom were the two main importers of honey in Europe, with a significant increase of 11% and 6%, respectively. Some countries recorded a higher increase in imports in value, such as Hungary (+88%), Croatia (+66%), and Bulgaria (+44%). However, the price of honey dramatically changed between EU Member States in 2018 (figure 1).

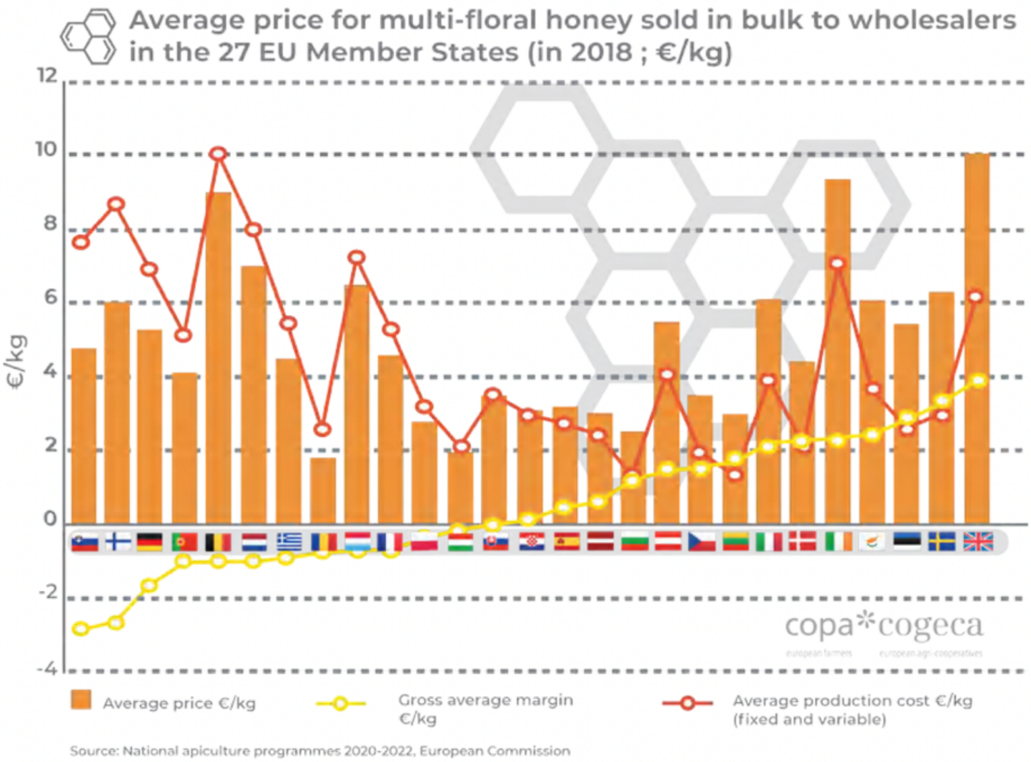

Figure 1: Average price for honey in EU Member State in 2018 (Copa-Cogeca 2020)

Despite the fact that the EU produced 283,000 tonnes of honey in 2018, it is not self-sufficient and imports about 40% of its honey from third countries. The European honey market is divided into different categories of countries. These categories include countries that primarily export their honey production to other EU Member States, such as Hungary, Poland, and Romania (figure 2). Additionally, there are countries that do not export their honey but instead import honey from other Member States or third countries, package it, and then re-export it to other Member States. Examples of such countries include Germany and Belgium. Lastly, there are countries that not only export their own honey production but also package and re-export imported honey. Spain, Portugal, and Poland are some examples of these countries.

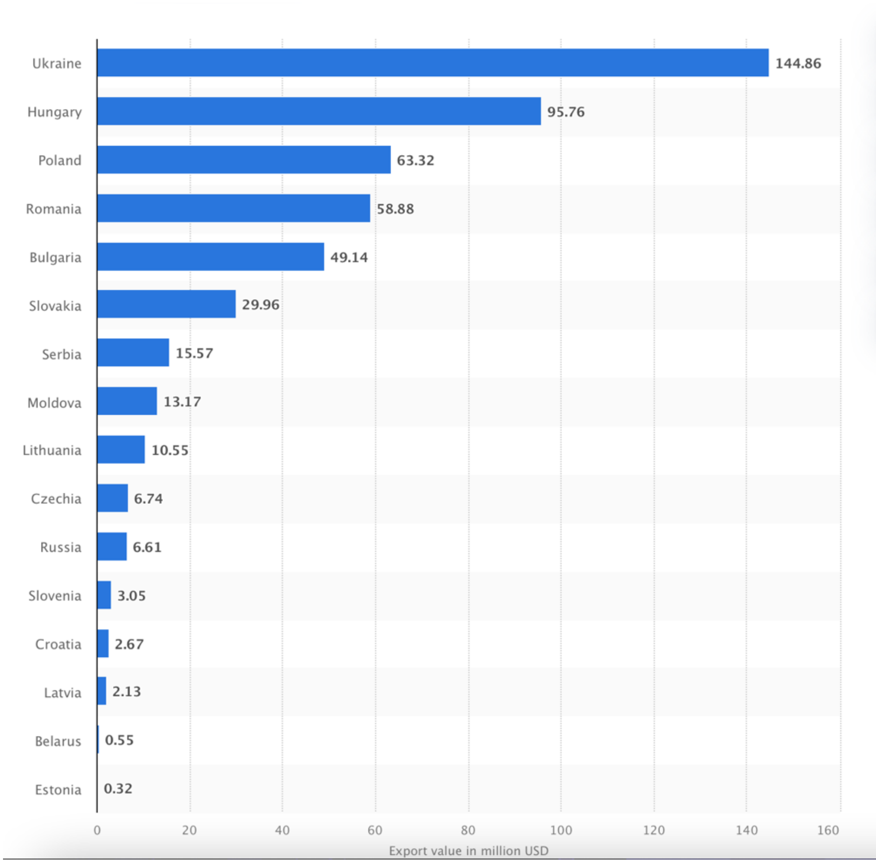

Figure 2: The chart includes export value of natural honey in Central and Eastern European countries in 2021 (in million U.S. dollars) (FAO 2022)

According to The National Hungarian Beekeepers' Association (2022), Hungary is one of the largest honey producers in the European Union and has one of the highest bee densities, with 13 hives per square kilometer. As a result, there are 1.2 million hives in total, cared for by 20,000 beekeepers. Hungarian bees produce an impressive 25-30,000 tons of honey annually, of which 60% is exported to other countries.

2.3 Beekeeping practises

2.3.1 Main products: honey and and other bee products

Beekeeping provides various primary products that have commercial value, including honey, wax, pollen, propolis, royal jelly, venom, queens, bees, and larvae. While some products are collected in nature, others are used as ingredients in various secondary products to enhance their quality and value. Despite the availability of synthetic substitutes for some primary bee products, such as those used in technology, food, and health products cannot be replaced with synthetic substances due to the wide range of benefits they provide. In some special applications, the synthetics may be more effective than primary bee products. Furthermore, the combination of different primary bee products support to enhance their overall biological value, which surpasses each individual benefits.

During the winter months, honey bees have unique ways of surviving the cold weather. Unlike many other animals, they do not hibernate. In nature, honey bees can consume their honey reserves, which become their food source, and the bees generate heat to keep warm. When the temperatures drop below 10 degrees Celsius, the bees at the center of the cluster consume honey and vibrate their muscles to generate heat (Simpson 1961). This process continues until the temperature inside the hive reaches a comfortable 30 to 37 degrees Celsius, as studied by Zacepins and Karasha (2013). However, a cluster of bees can still starve to death despite having honey frames in the hive because they only move up and down within the hive. This behavior of honey bees during the winter months is crucial for beekeepers to ensure the survival of their hives and develop strategies to help honey bees thrive in their natural habitats, supporting their important role in pollination and ecosystem services. Additionally, the combination of various primary bee products offers an overall biological benefit that surpasses the individual benefits of each product.

Honey is a thick liquid (figure 3) primarily consisting of two types of sugars known as glucose and fructose (Yaghoobi et al. 2008). These sugars make up most of the carbohydrates in honey, giving it its unique flavor and texture. In addition to glucose and fructose, honey also contains other sugars, including maltose, sucrose, and galactose, as reported in a study by White et al. (1962).

Figure 3: Honey extraction process (Photo: Kim 2022).

In table 1, the water content in honey can vary depending on how it was collected and processed, typically comprising around 17% of the composition. Along with sugars, honey contains small amounts of acids, proteins, and minerals, and the precise combination of these elements can differ based on the flowers the bees used to produce the honey and the geographical location of the production.

Average composition of U.S honeys and ranges of values (White, et al., 1962)

Component (% except pH and diastase valute)	Average	Standard deviation	Range
Water	<>17.2	1.5	13.4 - 22.9
Fructose	38.2	2.1	27.2 - 44.3
Glucose	31.3	3.0	22.0 - 40.7
Sucrose	1.3	0.9	0.2 - 7.6
Maltose (reducing disaccharides calculated as maltose)	7.3	2.1	2.7 - 16.0
Higher sugars	1.5	1.0	0.1 - 8.5
Free acids (as gluconic acid)	0.43	0.16	0.13 - 092
Lactone (as glucolactone)	0.14	0.07	0.0 - 0.37
Total acid (as gluconic acid)	0.57	0.20	0.17 - 1.17
Ash	0.169	0.15	0.020 - 1.028
Nitrogen	0.041	0.026	0.000 - 0.133
pH	3.91	-	3.42 - 6.10
Diastase value	20.8	9.8	2.1 - 61.2

Table 1: The average composition of honey and range value in U.S (White et al. 1962)

In figure 4, the pollen and nectar, which are known as nutritional components, including sugars, proteins, fatty acids (omega-3, and omega-6), essential amino acids, vitamins, and even macro- and microelements (Gemeda & Kebebe 2019).

Figure 4: Pollen and necta (Photo: Kim 2022).

In 2021, the largest global producers of bee pollen were China, Australia, and Argentina, with a production of approximately 1,500 tons per year. Bee pollen is a well-known functional food and is primarily composed of carbohydrates and water, with high protein (as shown in table 2), lipid, dietary fiber, mineral, vitamin, and antioxidant contents. Bee pollen is the primary food for worker bees to produce royal jelly or to be used directly as food for queen and worker larvae due to its high protein and lipid content.

The average composition of dried pollen

	Bee-collected		**Hand-collected**
	%[a]	%[b]	%[b]
Water (air-dried-pollen)	7	11	10
Crude protein	20	21	20
Ash	3	3	4
Ether extracts (crude fat)	5	5	5
Carbohydrate			
Reducing sugars	36	26	3
Non-reducing sugars	1	3	8
Starch	-	3	8
Undetermined	28	29	43

Table 2: The average composition of dried pollen (Schmidt & Buchmann 1992)

Royal jelly has been described as milk because it is rich in protein composition, and it is produced from secretions of the glands of worker bees (Crailsheim 1990). According to

Crailsheim's documents, worker bees select certain larvae who are initially fed royal jelly exclusively in specialized cells during development and are raised as queens. Upon emergence, the queen bee is taken care of with royal jelly throughout its entire life because only the queen bee is sexually mature and can maintain the number of bees in its hive. The bee queen also exhibits distinct behaviors and can live for multiple generations. The composition of royal jelly includes 60-70% water, 9-18% protein, and 10-16% carbohydrates (Ramanathan et al. 2018). This jelly also contains various antioxidant enzymes and collagen, which is a major protein found in human tissues such as skin, hair, nails, bones, and veins.

Bee bread is a part of the hive product resulting from the lactic acid fermentation of bee pollen by bacteria and yeasts, which is not commonly used by beekeepers. Although some of the nutritional components in bee pollen are destroyed during fermentation, the higher nutritional value and bioavailability of bee bread make it more digestible than bee pollen. Bee bread has a lower amount of proteins and fats, but it shows a higher amount of easily assimilated carbohydrates, free amino acids, and lactic acid.

Propolis, also called bee glue, is a sticky resinous substance produced by honey bees through the modification of bud exudates, flowers, and leaves with their secretions (enzymes) mixed with wax. Bees use propolis as a cementing material to seal off gaps and cracks in their hives. In figure 5, propolis was found and collected from the metal frame on the top of the bee hive. Propolis has been recognized as a valuable medicinal and nutritional resource that promotes overall well-being, as shown in table 3.

Figure 5: Propolis accumulated on the metal frames (Photo: Kim 2022)

According to table 3, the composition of propolis varies based on geographical, vegetation, and ecological regions, as well as the time and method of collection. Generally, propolis consists of 45-55% vegetable balms and resins (flavonoids, phenolic acids, and esters), 8-35% wax, 5-10% essential oils, minerals, and aromatics (such as pinene, viridiflorol, eudesmol, and tricosane), 5% pollen, 5% fatty acids, and 5% other organic compounds (Luo et al. 2021). The main responsible components of propolis for the exhibited biological activities, such as flavonoids, aromatic acids, chlorogenic acids, diterpenic acids, phenolic compounds and their derivatives, fatty acids, prenylated benzophenones, prenylated phenylpropanoid acids, and other secondary metabolites, have been identified. Beeswax is a naturally occurring biological polymer obtained from bee secretions, and its chemical composition varies according to geographic origin and differs depending on the honeybee species.

pH and Nutrient Content of Honey Propolis Trigona From Masamba, South Sulawesi

pH and Nutrient Content	**Quantity**
PH	4
Protein	0.43 %
Moisture Level	17.11%
Carbohydrate	21.94 %
Total Phenol	190.3 mg/100 g
Quercetin	17.28 mg/100 g
Vitamin A	4.49 ug/g
Vitamin C	302.26 ug/g
Vitamin E	59.36 ug/g
Calsium (Ca)	292.5 ppm
Magnesium (Mg)	261.5 ppm
Zink (Zn)	0.71 ppm

Table 3: The average composition of propolis in Indonesia (Usmana et al. 2016)

Table 4 shows that beeswax is primarily composed of esters, fatty acids, alcohols (Tulloch et al. 1980), and hydrocarbons, including linear wax monoesters, free fatty alcohols, and hydroxy monoesters derived from palmitic and oleic acids. It also contains 15-hydroxy palmitic acid and complex wax esters containing diols (Pratt 2000). Beeswax is a solid mixture (as shown in figure 6) with multiple components at room temperature, and it finds application as an additive in the food industry, cosmetics, and candles. Its versatile nature is attributed to its ability to serve as a thickener, drug carrier, binder, and release retardant in pharmaceutical preparations.

Composition of beeswax (after Tulloch, 1980). Major compounds are those forming more than 1% of the fraction. The number in brackets indicates the number of compounds making up at least 1 % of the unfractionated, pure wax. The number of minor compounds, those with less than 1% of the fraction, is only an estimate.

Description	% of fraction	Number of components in fractoin	
		Major	Minor
Hydrocarbons	14	10 (5)	66
Monoesters	35	10 (7)	10
Diesters	14	6 (5)	24
Triesters	3	5	20
Hydroxy monoesters	4	6 (1)	20
Hydroxy polyesters	8	5	20
Acid esters	1	7	20
Acid polyesters	2	5	20
Free acids	12	8 (3)	10
Free alcohols	1	5	?
Unidentified	6	7	?
TOTAL	**100**	**74**	**> 210**

Table 4: The average composition of beeswax (Tulloch, et al. 1980)

Figure 6: Beeswax (Photo: Kim 2022)

2.3.2 By- porducts: slum gum

The term "slum gum" is commonly used by beekeepers to refer to the residual material left after beeswax is rendered (figure 7)

Figure 7: honeycomb, beeswax, and by-products (Photo: Kim 2022)

Results of Kole (2021) showed that 190 grams and 980 grams of beeswax were respectively extracted from one kilogram and five kilograms of honeycombs, which was around 20% of the total weight of the comb. The highest efficiency of 25.01% was obtained when the extractor was loaded with three kilograms of honeycomb under optimized conditions. This indicates that a significant amount of honeycomb, ranging from 75% to 80%, is left as dried refuses or slum gum after beeswax extraction.

Unlike wax obtained from cappings and honeycombs, which is relatively pure, wax from brood combs used by honeybees to store honey can contain a diverse array of substances, including cocoons from bees and wax moths, excrement from bee larvae, mites, pollen, propolis, and bee parts. Research has revealed that slum gum contains bioactive compounds with antioxidant and antimicrobial properties that can potentially boost the immune system of fish and protect them from diseases, as demonstrated in a study by Kaschubek et al. (2018). Additionally, the use of honeycomb extract in the diet of Nile tilapia was found to improve growth and immune response, as reported by Hassanein (2014). Furthermore, slumgum is rich in various bioactive compounds, such as phenolic compounds, flavonoids, and tannins, which possess potent antioxidant and anti-inflammatory properties. These compounds have the potential to safeguard the body against oxidative stress, inflammation, and chronic diseases, such as cancer, cardiovascular disease, and diabetes, as highlighted in a recent study by Gaber in 2006.

Utilizing slum gum from bees as a mulch in horticulture has the potential to offer considerable economic advantages. One such benefit is the ability to lower the costs of purchasing and

applying synthetic fertilizers, herbicides, and pesticides. Slum gum is a readily available and affordable material that can substitute artificial inputs, reducing production costs for farmers.
Furthermore, incorporating slum gum as a mulch can enhance soil quality and the health of plants, resulting in improved crop yields and quality. This can lead to increased profits for farmers as they can sell higher quality produce. The research conducted by Babarinde (2013), has shown the use of organic mulches, such as slum gum could also offer long-term economic benefits. Organic mulches would increase the productivity and sustainability of land farms, improve soil quality, and decrease erosion, resulting in more reliable, and get profitable agricultural systems. Extra slum gum as a feed additive, which was also utilized as animal feed, specifically for *Oreochromis niloticus*, provided significant economic advantages for farmers involved in animal farming.

However, some of the main challenges of applying slum gum in feed additives for tilapia were the potential for oversupply or less supply of certain nutrients. The nutrient content of slum gum could vary depending on several factors, including the source of the bees and the season in, which it is collected (Human & Nicolson. 2006). Those could lead to imbalances in the nutrient content of the feed, which could negatively impact fish growth and health. According to the studies of Furuya and colleagues, the low essential amino acids could be matched with slow growth, and poor feed utilization in fish (Furuya et al. 2023), which slum gum is identicated to high carbohydrates, complex chemical content, and fluctuated protein content (de Jesus 2020).

Furthermore, the potential impact of mycotoxins has relevance with slum gum on fish health and growth that should be considered. Mycotoxins, which had known as toxic compounds produced by fungi, could contaminate various feed sources (Ke et al. 2018). The contaminated slum gum covered worse quality, which caused a range of health problems in fish, reduce growth, liver damage, and immune suppression (Oliveira & Vasconcelos 2020). Therefore, it becomes more important to carefully monitor slum gum.

2.3.3 Ecosystem services (pollination)

The stability of pollination services, both in the short and long term, relies heavily on the presence of healthy pollinator populations, including bees, hoverflies, moths, butterflies, and beetles. These pollinators are crucial for the reproduction of a large majority of flowering plants, and without them, ecosystems and business value chains would be severely impacted, resulting in cascading effects. Loss of pollinators would not only lead to a decline in fruits, nuts, and vegetables in our diets, but also affect other important raw materials and products such as vegetable oils, cotton, flax, and plant-based pharmaceutical and cosmetic products. In essence, pollinators play a pivotal role in maintaining the health and resilience of terrestrial ecosystems, which in turn provide essential services to businesses and society as a whole. However, there is a concerning trend of declining pollinator populations worldwide, including in Europe, with many species at risk of extinction, resulting in a deficit in pollination. This poses a significant threat to the functioning of managed and natural ecosystems, with businesses facing potential shortages of raw materials, a decline in crop quality, and challenges with supply chain security. This decline in pollinators has far-reaching implications, and urgent actions are needed to address this issue and ensure the continued stability of pollination services for the benefit of ecosystems, businesses, and society at large.

Insect-pollinated crops are essential for providing vital micronutrients, such as vitamins, folic acid, and dietary diversity, even though staple crops that are wind-pollinated or largely self-pollinated may constitute the majority of human food by volume (Kremen et al. 2002). Pollinators play a critical role in providing ecosystem services by enhancing or stabilizing yields of approximately 75% of global crop-plant species (Klein et al., 2007). The demand for insect pollination has witnessed a significant increase due to the expansion of insect-dependent crops worldwide, resulting in a threefold rise since 1961 (Aizen & Harder 2009). However, relying solely on managed honey bees for pollination may prove inadequate, as their activity may not always ensure the required quantity and quality of pollen at the appropriate time and place (Garibaldi et al. 2011). There exists a strong correlation between pollinator diversity and sustainable crop pollination. Natural habitats that support wild pollinators contribute to a resilient and complementary pollination service that enhances crop yields (Kremen et al. 2002). Because of the numerous threats faced by pollinators, relying on a single species for pollination services is a precarious agricultural strategy (Kearns et al. 1998).

2.3.4 Applying of bee product in animal feeding

The incorporation of slum gum into animal feed can lead to significant economic benefits due to its relatively high protein and fat content, making it suitable for submission. This can result in a reduction in the cost of feed production and an improvement in the nutritional quality of the feed. As a result, economic benefits can lead to better growth rates and higher survival rates for animals on farms, ultimately resulting in higher profits for farmers. If the cost of feed production could be reduced, farmers could save money, reinvest those savings into other areas of their farms, and increase efficiency or profitability.

For instance, a study conducted in Nigeria found that broiler chickens fed a diet containing maize, which was replaced in varying percentages with slum gum, were comparable in terms of feed intake, weight gain, and feed efficiency. While slum gum contains important nutrients such as 0.2% phosphorus, 0.4% potassium, and 5-6% nitrogen, as reported by Morales-Corts et al. (2010), another study conducted in Brazil found that dairy cows fed a diet containing propolis had improved milk quality compared to those fed a conventional diet. The researchers attributed the improved milk quality to the presence of bioactive compounds in slum gum, such as phenolic acids and flavonoids (Soltan et al. 2020).

Bee slum gum is the final product from honeycomb melting, which contains the potential as a valuable feed ingredient in diets for rabbits. As noted by Babarinde's team, honeycomb typically contains protein and energy sources, such as pollens, brood lining, and eggs, which can be harnessed by using slum gum meal in a feed resource (Babarinde et al. 2011). Furthermore, the nutrient content of slum gum meal offers a cost-effective alternative to maize in growing rabbit diets. By replacing 25% of maize with honey slum gum meal, farmers can reduce production costs and improve their income. This encourages further production, making more meat available for human consumption. Additionally, using slum gum meal resources may help reduce pest infestations in beekeeping areas, which can result in significant financial losses and low incomes for farmers.

Another example is a study conducted by the Ladoke Akintola University of Technology, which investigated the nutritional potential of slum gum meal on the performance characteristics of growing rabbits (Ojebiyi et al. 2013). Naturally, those are primary nutrients such as protein, carbohydrates, fatty acids, and vitamins, which need to supply for rabbits (Cheeke 1986), which slum gum entirely supplies when mixed with the based feed. The study found that incorporating slum gum into the rabbits' feed led to improved growth rates and feed conversion ratios. Similarly, the use of the feed additive Vinivet, which contains slum gum and bee bread, was found to increase production, improve quality, and reduce the cost of eggs and meat in broiler chicks (Andrianova et al. 2013). These findings suggest that the incorporation of slum gum into animal feed can have both economic and health benefits for farm animals.

Typically, the industry-standard feed for tilapia contains a balanced combination of macronutrients and micronutrients, which formulate to include nutrient sources, such as fish meal, soybean meal, or corn gluten meal. In addition, the fat and carbohydrates come from fish

oil, vegetable oil, or wheat flour. Moreover, the high chitin concentration in the parts of insect bodies contained in slum gum is a valuable addition to nutrient composition. In addition to these macroelements, slum gum is also rich in a range of microelements, as reported by Őrösi (1957). These characteristics make slum gum a valuable resource for agriculture and aquaculture.
As an organic and sustainable source of nutrients, slum gum could be a potential alternative to chemical fertilizers and supplements, therewith promoting environmentally friendly practices. In contrast, honey bee slum gum is not a significant source of protein, carbohydrates, or fat. In spite of that, it contains small amounts of minerals such as zinc, copper, iron, and vitamins B1, B2, and B6. Nowadays, some feed additives are becoming increasingly more expensive and have negative impacts on the environment. For that reason, slum gum has the potential to be an attractive alternative to synthetic additives and promote more sustainable farming practices.

2.4 Aquaculture

Fish production is a critical aspect of global food security. Those provided a significant source of protein for millions of people on the planet. As the population continues developing, the demand for fish is also increasing. Therefore, it is crucial to ensure that fish production keeps pace with the growing speed to ensure food security (Krkošek 2006). While aquaculture has the potential to feed and nourish the world's growing population, sustainable growth is an important key. The expansion of aquaculture has often resulted in environmental damage. Therefore, while minimizing negative impacts head to the environment, sustainable aquaculture development is essential to improve the rising demand for aquatic foods, less overfishing, and pollution (Ortiz Almirall et al. 2022). Overfishing caused not only the food supply but also the livelihoods of those dependent on fishing, which has head to the depletion of fish stocks. In any case, pollution also has pessimistic consequences on both wild and fish farms, which reduces their productivity and value (Kotaro Ono et al. 2016). In this case, aquaculture can harm the environment. As it happens, fish farms cause habitat destruction in coastal lines, water pollution, and the introduction of non-native species.

2.4.1 Economical importance production trends

The economic impact of the global fisheries and aquaculture industry is becoming increasingly apparent, as it not only provides a vital source of employment but also plays a critical role in addressing the world's food and nutrition demands.

According to FAO, global aquaculture production has achieved a remarkable milestone, reaching a record high of one hundred million tons in 2020. This achievement has brought about a total value of nearly three hundred billion USD, reflecting the significant economic consequences of the industry. Continuously, Asia dominates aquaculture production, accounting for more than ninety percent of the total output. In 2020, in spite of the record of 14.5% growth in Africa, the primary sector employed an estimated nearly sixty million individuals, and around six hundred million livelihoods were partially reliant on fisheries and aquaculture. Africa witnessed a decline in production in the same year, primarily due to setbacks in Egypt and Nigeria. However, the consumption of fish and seafood for human consumption had more than doubled since the 1960s, reaching an average of higher than twenty kilograms per person. The surge in consumption can be attributed to the rising global demands for food and nutrition, leading to record production of more than two hundred million tons in 2018, with aquatic animals accounting for approximately 175 million tons, and algae constituting 36 million tons. In the first year of the 2020s, the record-high production levels with a total value of overcome four hundred billion USD (FAOSTAT 2021). Despite the industry's challenges, such as overfishing, climate change, and habitat destruction, the industry's continued growth and development will be essential for ensuring food security, supporting livelihoods, and promoting sustainable economic development worldwide.

In the economic strategy, the aquaculture industry has witnessed significant transformations in recent years. Surprisingly, the shift towards alternative feeds, improved feed efficiency and increased productivity in aquaculture systems. Additionally, replacement feeds have emerged with a decline in the use of fishmeal and fish oil and an increase in plant-based and other alternative feeds. These changes emphasize the need for sustainable management and development of the industry to ensure its continued success. As the global fisheries and aquaculture industry continues to grow and evolve, understanding its ecological impacts and adopting sustainable practices will be critical for meeting future food and nutrition demands while maintaining the livelihoods of millions of people.

2.4.2 Nutritional challenges in aquaculture

While the worldwide increase in demand for animal products has strained natural resources and raised concerns regarding the environmental impacts. One of the primary concerns is the use of traditional feed resources like corn and soybean, which have high environmental costs associated with them (Pesti & Miller 1993). To address this problem, there has been growing interest in the replacement and reduction of traditional feed resources with sustainable feed sources in animal feed. These green products have a lower environmental footprint compared to traditional feed resources and are thus a potential solution to reducing the negative impacts. The challenges posed by traditional feed resources in animal agriculture are also applicable to the aquaculture industry. As the global demand for seafood continues to rise, so does the pressure to produce more fish at a faster rate. However, the use of traditional fishmeal and fish oil as primary sources of nutrition for farmed fish is becoming increasingly unsustainable due to the environmental costs associated with their production. Furthermore, these resources are becoming scarcer and more expensive, making it economically unfeasible to continue relying on them. Thus, alternative sources of nutrition, such as plant-based protein sources and microbial-derived ingredients, are being explored to reduce the dependence on traditional feed resources in aquaculture. These alternatives have the potential to not only address environmental and economic concerns but also ensure the long-term sustainability of the aquaculture industry. Examples of green products include algae, seaweed, byproducts, and alternative protein sources like mealworms and black soldier fly larvae. These sustainable feed sources have the potential to decline environmental issues, such as deforestation, water pollution, and greenhouse gas emissions, while still maintaining the nutritional needs of all animal production systems, including aquaculture (Boissy 2011).

2.4.3 Alternative protein sources in aquaculture

Algae and seaweed represent two potential alternative feed sources that are highly sustainable and offer significant environmental advantages. From the part, algae have been abundant in protein and other essential nutrients, which are suitable for animal feed, and they necessitate minimal land, water, and other resources to produce. Replacing conventional fish meals with algae-based protein in aquaculture, according to Kovač et al. (2013), decreases dependence on wild-caught fish for feed, mitigates overfishing, and eases the pressure on marine ecosystems.

On the other hand, seaweed is obtained safely from the ocean and serves as a feasible feed alternative for various livestock, including cows, pigs, and poultry, with beneficial effects on animal health and performance, as reported by Rajauria (2015).

By-products such as distillers' grains and soybean hulls are being utilized as feed sources for cows in the dairy industry, thus reducing waste and the environmental impact of the industry. For example, mealworms and black soldier fly larvae are being used as protein sources in chicken feed in the poultry industry, which are more sustainable and cost-effective than traditional protein sources like soybean meal and fish meal. The utilization of green products in animal feed is crucial for global food security, especially in fish production. Sustainable fish farming practices, such as incorporating alternative feed sources like algae and insect-based protein, can help to reduce reliance on wild fish for feed and contribute to sustainable fish production practices (Ramadan et al. 2015). The implementation of these green products in animal feed can contribute to more sustainable and friendly environmental practices in animal agriculture.

In intensive aquaculture systems, nutritionally sound feed is crucial for efficient fish growth and production. However, faulty feed can lead to reduced productivity and environmental issues such as the accumulation of wasted feed. Therefore, there is a growing need for low-cost, nutritionally optimal diets with high-quality ingredients. Soybean meal has been identified as a promising alternative protein source for fish meals in aquaculture feeds due to its high protein content, favorable amino acid profile, and digestibility in fish. Other ingredients such as milk powder, with its rich content of protein, carbohydrates, and essential vitamins and minerals, also provide valuable nutritional benefits to fish feed formulations. By carefully selecting high-quality feed ingredients, aquaculture farmers can ensure healthy fish growth and sustainable production practices.

According to Bhosale et al. (2010), that study had shown that soybean meal is highly digestible in fish, making it a valuable ingredient in fish feed formulations. It has also been extensively studied as a fish meal replacer in diets for many fish species, owing to its relatively balanced amino acid profile, reasonable price, and consistent supply. Soybean meal contains approximately 40% protein and 20% oil, with the remaining portion consisting of carbohydrates and ash. Milk powder, specifically Nestles milk powder, is another protein source used in fish feed formulation. It is rich in soluble vitamins A and D, minerals, and contains 20 standard amino acids. Milk powder provides approximately 36% protein and 52% carbohydrates, including lactose and calcium. Its high nutritional value makes it a suitable ingredient for fish

feed formulation. The use of partly skimmed milk powder, along with sucrose, provides additional nutrients and binding properties to hold the feed together in fish feed formulations.
Recent studies have raised concerns about the potential negative impact of chitin on fish performance and nutrient digestibility with insect meal, especially larvae, a common protein source in fish feed, which has been found to contain approximately 5.4 to 9.0 percent chitin on a dry matter basis (Eggink et al. 2022). While Shiau (1999) researched chitinolytic activity and the potential for chitin degradation by various intestinal enzymes, it remains unclear which fish species can digest chitin and to what extent. Although there are indications that chitin may impair the fish performance, which have been investigated how to potentially improve the applications of insect meal in fish feed by reducing the chitin content. Addressing the knowledge gap of Eggink et al. (2022) is essential to optimize the nutritional quality of fish feed and ensure optimal growth and development of fish species that rely on larvae as a protein source. Further research is needed to evaluate the impact of chitin on fish performance and explore methods to reduce the chitin content in insect meals for use in fish feed.

2.5 Nile Tilapia

Tilapia, or Nile tilapia (figure 8) is a popular fish species in aquaculture and fish farming, has undergone a scientific name is *Oreochromis niloticus* Linnaeus (1758) (FAO 2018).

Figure 8: *Oreochromis niloticus* , known as Nile tilapia. Source: https://www.hatcheryinternational.com/

2.5.1 Scientific Classification of Nile Tilapia

Phylum	Chordata
Class	Actinopterygii
Order	Cichliformes
Family	Cichlidae
Genus	Oreochromis
Species	*O. niloticus*

2.5.2 Distribution of Nile Tilapia

Nile tilapia is a tropical freshwater fish, which introduces in several countries worldwide. For instance, it distributes in tropical, subtropical Africa, and the Middle East, including the Nile River, Niger River basins, lakes Tanganyika, Albert, Edward, George, in Yarkon River, etc... (Trewavas 1983) (figure 9).

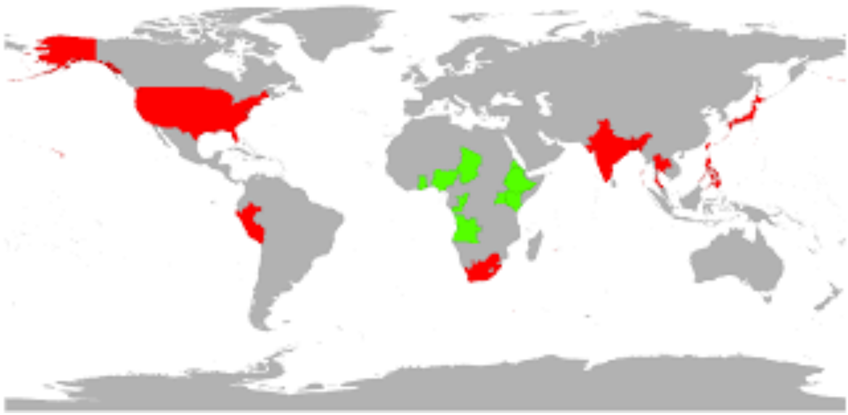

Figure 9: Native (green) and introduced (red) ranges of *O. niloticus* globally (Data source: GISD 2012).

2.5.3 Feeding Habit of Nile tilapia

Tilapia is an omnivorous grazer, which has been able to filter feed by entrapping suspended particles, and feed on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus, and bacterial films associated with detritus, the main source of nutrition is obtained by surface grazing on periphyton mats (FAO, 2023).

2.5.4 Economical importance and breeding of Nile tilapia

Tilapia remains a highly desirable fish for its mild taste, versatility in cooking, and relative affordability. In addition, tilapia is favored in aquaculture and fish farming for its fast growth rate and hardiness (Njiru 2006). The life cycle of tilapia involves several stages, starting with broodstock breeding, where adult tilapia with desirable traits are selected for reproduction. Broodstock breeding can be achieved through hormonal induction or natural spawning, with hormonal induction allowing for more control over the breeding process and larger and more consistent broods (Kpelly et al. 2022). Once the broodstock has spawned, the fertilized eggs are collected and incubated until they hatch into fry, which are then moved to nursery ponds for several weeks until they reach fingerling size. During the grow-out period, the tilapia fingerlings are raised until they reach market size and are fed a balanced diet to promote growth and development. The timing of harvest and sale is crucial to ensure optimal quality, as tilapia must be sold while still fresh. To improve production and diversify the yield, Nile tilapia are often bred in polyculture with other species, such as carp and catfish, in various regions. Furthermore, Nile tilapia exhibits a high level of adaptability to different environmental conditions, such as variable water temperatures, low oxygen levels, and high salinity (Mungkung et al. 2013). This versatility allows for the species to be farmed in diverse settings, ranging from freshwater ponds to brackish water systems and even marine cages.

Tilapia meat is renowned for its impressive nutritional profile, featuring low-fat and high-protein ratios (Kpelly et al. 2022). Notably, that is an excellent source of nutrition for those seeking to reduce their overall fat intake while still meeting their daily protein requirements. Moreover, tilapia is a low mercury fish, when compared to other ones may contain higher levels of mercury. Essential nutrients, including protein, unsaturated fatty acids, such as omega group, and vitamins are high concentration in tilapia meat (El-Asely et al. 2014). However, it is worth noting that the nutritional value of tilapia meat can be influenced by factors such as farming practices, feed quality, and the age and size of the fish.

2.6 Circular Economy

Alternative feed sources have become increasingly important in modern agriculture because they offer a range of benefits over traditional feed sources. These benefits include cost savings, reduced environmental impact, improved animal health and welfare, and increased profitability.

In agriculture, both farm animals and aquaculture production apply alternative feed sources to serve several functions. Initially, these sources provide nutrients for the animals during the raising term because of the range of nutrients, including carbohydrates, proteins, fats, essential vitamins, and minerals. The other important aspect of by-product feed sources is that they offer a cost-effective alternative to traditional ones. While the old-fashioned sources have been using corn, soybean meal, or alfalfa, which have become too expensive, and fluctuate based on market conditions. Furthermore, these sources will offer a more stable and cost-effective option, as they may be produced locally. Thus, their prices will be less affected by market conditions. New feed sources can play a role in reducing the environmental impact of agricultural production. Many traditional feed sources have required significant amounts of land, water, and other resources to produce. Alternative feed sources become more sustainable, require fewer resources, and reduce the environmental footprint of agriculture (Franco et al. 2022).

Nowadays, insects are used as alternative protein sources in animal feed, such as mealworms, black soldier flies, or crickets. Insects, and their products, including their by-products, contain high protein and essential amino acids (van Huis 2022). In addition, by-product resources can provide health benefits for animals. For example slum gum contains high nutrients, including protein content, carbohydrates, and minerals (Ramadan et al. 2015).

3. Materials and methods

This experiment was conducted in the experimental station of the Aquaculture Department at the Hungarian University of Agriculture and Life Sciences in Kaposvár (figure 10). The experiment was carried out from February to April in 2023.

3.1 Experimental fish stock

Half year old juvenile Nile tilapia were used for for the experiment which were originated from Kaposvár Campus from own broodstock reproduced in the Campus.

Figure 10: The experimental station of the Aquaculture Department at the Hungarian University of Agriculture and Life Sciences in Kaposvár (Photo: Kim 2023)

All protocols that involved the utilization of fish in this research were executed in compliance with the Hungarian statutory regulations concerning experimental animals, which were subjected to scrutiny and endorsement by the National Scientific Ethical Committee on Animal Experimentation. In order to reduce the discomfort of the fish, every possible measure was taken, which encompassed the application of eugenia caryophyllus oil (10 ml) to induce anesthesia before obtaining measurements (figure 11).

Figure 11: Eugenia caryophyllus oil (10 ml): anesthetic compounds (Photo: Kim 2023)

3.2 The experimental design and rearing conditions

The experimental method employed in this four weeks study utilized a recirculation aquaculture system (RAS) to investigate the effects of certain variables on tilapia individuals. A complete randomized design (CRD) was utilized to set up the experiment, with a total of 108 tilapia individuals (table 5), initially weighing between 30 to 60 grams, randomly distributed across 9 tanks (200L each) in triplicate, with 12 fish per tank (figure 12). The experiment involved randomly selecting a sample of fish from each group and dividing them into different treatments. The weight and length of each fish were recorded at the beginning and end of the four-week experiment using a scale with units in grams (figure 13) and a centimeter ruler to measure the total length of the fish (figure 14). Additionally, a camera was used to capture images of the fish. The first treatment (control group) received base feed without slum gum. The feed were designed to be iso-nitrogenous and iso-energetic (table 6). This feed contained commerial feed produced for adult carp and tilapia (proximate composition of the feed can be seen in table 7, and 160g/kg fishmeal (crude protein 60%) to set the protein level. In the second treatment (SG10) fish the base feed where 10% were replaced by slum gum. The third treatment (SG30) fish received base feed where 30% percent was replaced by slum gum.

Figure 12: Experimental fish (Photo: Kim 2023)

Figure 13: Body weight measurement by gram scale (Photo: Kim 2023)

Figure 14: Measurement involved using a centimeter ruler to measure the total length of the fish, which is the length from the tip of the snout to the tip of the longer lobe of the caudal fin (Photo: Kim 2023).

Slots	S6-C	S9-C	S11-C	S10-SG10	S12-SG10	S13-SG10	S7-SG30	S8-SG30	S14-SG30
***O. niloticus* initial weight (gram)**	30	52	31	32	36	50	30	51	35
	38	48	43	42	35	41	47	56	32
	38	50	53	38	37	53	45	36	49
	57	38	45	47	55	48	38	46	50
	44	38	56	58	59	45	55	55	50
	43	45	56	49	55	35	46	37	56
	58	52	49	57	55	31	51	50	49
	58	54	47	51	51	54	49	39	45
	54	45	53	58	46	50	57	46	53
	53	49	40	34	41	59	55	55	54
	52	40	48	57	36	57	46	54	43
	46	38	38	36	59	37	43	38	38
Mean	47,6	45,8	46,58	46,8	46,58	46,67	46,92	47,08	46,2
Sd	9,17	5,99	7,65	9,91	9,62	8,98	7,63	7,69	7,71
Group mean±sd	46.6±0,9			46.6±0.11			46.7±0.416		

Table 5: The initial weight of 108 individual tilapnia of this experiment (gram)

	Control	SG10	SG30
Commercial feed (g/kg)	840	740	540
Fish meal (g/kg)	160	160	160
Slumgum (g/kg)	0	10	300
***according to calculation**			
*CP (%)	32.28	32.12	32.71
*CF(%)	6.7	6.8	7.1

Table 6: The experimental diets contained

Dry matter	88%
Crude protein	27%
Fat	4.6%
Crude fibre	2.3%
Lysine	1.3%
Methionin	0.7%
Ca	0.9%
P	0.7%
Na	0.1%
Vitamin A	15000NE
Vitamin D3	1200NE
Vitamin E	75 mg/kg

Table 7: Commercial fish feed for adult tilapia produced by Haltáp Ltd. Hungary

The feed was fixed at 2.5% of biomass (table 8) and distributed by hand four times per day during the four weeks of the experiment.

Treatments	**Control**			**SG10%**			**SG30%**		
Tanks	S6	S9	S11	S10	S12	S13	S7	S8	S14
Total body weight of 12 individual in each tank (gram)	571	549	559	559	565	560	562	563	554
The feed given (gram)	92,79	89,21	90,84	90,84	91,81	91,00	91,33	91,49	90,03

Table 8: Feed was fixed at 2.5% of biomass

3.3 Origin of the Slum gum materials

The slum gum materials, which were used in the experiment, were collected from the Georgikon campus of the Hungarian University of Agriculture and Life Sciences. Bee slum gum, the residual substance left after extracting beeswax from harvested combs, requires proper cleaning and drying before use. First of all, dried refuses are removed impurities such as mosses, dirt, and dead insects. After then, rinse it with clean water to eliminate any remaining debris or dirt. Subsequently, the slum gum is dried with a clean towel to remove excess water. The slum gum is spread in a single layer on a flat surface, like a tray, and placed in a well-ventilated area, for example in a room with a fan or near an open window. Allowing the slum gum to air dry for several days until it becomes hard and brittle, rotating it periodically to ensure uniform drying. In this experiment, slum gum is applied at a high temperature to get dry at 60°C (figure 15).

Figure 15: The machine was used to get dry slum gum in 60°C (Photo: Kim 2023)

Figure 16: Slum gum before (left) and after (right) treatting to storage and using (Photo: Kim 2023)

Proper storage of slum gum is essential to ensure that it remains safe and suitable for use as feed. Once completely dry, slum gum should be stored in an airtight container in a cool, dry place (figure 16). During the storage period, it is important to check for signs of mold or discoloration. If the slum gum appears fuzzy or slimy, or if it has changed color, it may be spoiled and should not be used.

Additionally, it is recommended to smell the slum gum to detect any off-odors. A sour or rancid smell indicates spoilage and the slum gum should not be used. Moreover, if the slum gum is too soft or crumbly, it may have lost its nutritional value and should not be used. To keep track of storage, it is advisable to record the date of storage and check the recommended storage period or expiration date of the slum gum. The slum gum samples were also analyzed before the the trials to ensure the nutrient values (table 9). The sample selected from the Georgikon campus in 2022 was preferred due to its elevated protein content and lower moisture levels in comparison to other samples, which consequently posed a reduced risk of mycotoxin contamination.

Slum gum samples	Sample 2022 (used)	Sample 2022 (Győr)	Sample 2023
Crude protein (%)	25,0	18,1	24,9
Crude fat (%)	23,3	49,2	26,7
Ash (%)	2,7	1,7	2,9
Moisture (%)	5,9	7,1	10,3

Table 9: The composition of slum gum samples

3.4 The preparation of the xperimental diets

Feed was fixed at 2.5% of biomass. The tank biomass was measured to adjust the daily feed portions every second week by a portable measuring scale (MMX, China, accuracy±1 gram).
The procedure of experimental feed production. In figure 17 and 18, the ingredient where grained and mixed together by hand.

Figure 17: Slum gum and feedstuff were grained and filter to fit with tilapia mouth size (Photo: Kim 2023)

Figure 18: Slum gum and feedstuff were mixed with water 200 ml/Kg containing 1% gellatin by hand (Photo: Kim 2023)

In figure 19 illustrates the the pure feed for the control group, and the mixed feed are grinded by manual machine. In drying process, where the pure feed and mixed feed are separated, which were spread out on individual trays. These trays are then left at room temperature for 24 hours (figure 20) to allow the feed to dry before it is cut, and repared for feding (figure 21).

Figure 19: Feedstuff was grinded by manual machine (Photo: Kim 2023)

Figure 20: Drying process, the pure feed and mixed feed are separated (Photo: Kim 2023)

Figure 21: The pure feed and mixed (Photo: Kim 2023)

3.5 Water quality

Throughout the trial, regular monitoring of water parameters was conducted to ensure optimal conditions for the fish (figure 22). The following parameters were measured and recorded: temperature (°C), NH_4^+ (mg/L), NO_3^-(mg/L), NO_2^- (mg/L), dissolved oxygen (mg/L), and pH. The temperature was maintained at an average of 24.5±0.2°C, dissolved oxygen at 7.2±0.5mg/L measured every week, NH_4^+ at 0.50±0.02 mg/L, NO_3^-at 28.5±0.19 mg/L, NO_2^- at 0.16±0.02 mg/L, and pH at 8.0±0.5, measured on a two-weekly basis.

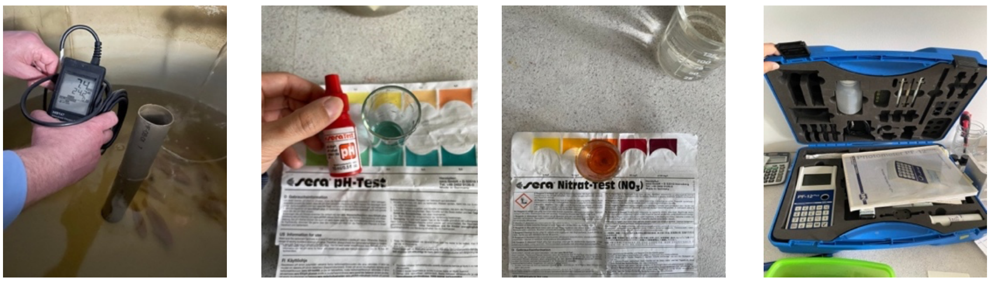

Figure 22: Water parameters was checked regular to ensure optimal conditions for the fish (Photo: Kim 2023)

The monitoring of these water parameters was crucial to ensure that the experimental conditions remained consistent throughout the study period, and any fluctuations were recorded and accounted for in the analysis of the results. Adequate space and water quality will be provided to minimize stress and ensure healthy growth.

3.6 Calculations

The weight gain (WG) = Wf – Wi
Feed conversion ratio (FCR) with FCR = weight of feed consumed (g)/weight gain (g)
Specific growth rate (SGR) with SGR=100*lnWf-lnWi/t
Protein Efficiency Ratio (PER) = weight gain(g)/protein intake(g)
Condition factor (CF) = Total BW/TL^3 × 100 and TL = total body length (cm)
Survival rate (S %) = 100× number of survived fish /numbers of stocked fish

3.7 Statistical Analysis

In this study, ANOVA was performed by using R studio/R cmdr software package, which was applied for the evaluation of the morphometric characters and growth rate of *Oreochromis niloticus*.

The coefficient of variation (CV) is used to compare variability between different measures and is defined as the ratio of the standard deviation and the mean.

CV%: 0 – 10% is very homogenous

10 – 20% is homogenous

>20% is heterogeneous

In order to determine whether any of the differences between the means are statistically significant, the p-value is used to compare the significance level to assess the null hypothesis. A significance level (α) of 0.05 indicates a 5% risk of concluding that a difference exists when there is no actual difference.

P-value ≤ α: The differences between some of the means are statistically significant.

P-value > α: The differences between the means are not statistically significant.

Post hoc Tukey's multiple comparison test was then utilized to check the means between groups and determine any significant differences among the treatment groups.

4. Results and discussion

4.1 Body weight and feed utilisation

According to thhe final measurement of the body weight was shown in table 10, the experiment indicate that the body weight of tilapia remained stable when fed with the tested product. There was significant p-value be found ($p \leq 0.05$). This suggests that the tested product was effective in maintaining the body weight of the tilapia stable throughout the experiment.

The absence of significant differences in the final body weight of each individual tilapia (as shown in figure 23), condition factor (CF), and survival rates (S%) among the different diet groups were found after ANOVA statistical analysis. However, significant variations ($p \leq 0.05$) were observed in weight gain (WG), feed conversion ratio (FCR), protein efficiency ratio (PER) and specific growth rate (SGR) between the group treatments and the control group.

Slots	S6-C	S9-C	S11-C	S10-SG10	S12-SG10	S13-SG10	S7-SG30	S8-SG30	S14-SG30
The final body weight of each individual tilapia (gram)	50	60	57	46	57	62	55	55	56
	75	73	80	42	72	80	41	65	61
	86	63	51	78	79	62	66	62	50
	82	84	74	79	67	59	56	72	57
	84	61	71	72	65	63	78	76	64
	37	59	70	66	44	81	74	50	56
	65	56	62	65	54	77	54	48	38
	70	71	62	76	50	62	73	58	64
	75	49	44	73	80	49	63	64	64
	73	102	55	58	91	75	72	75	62
	66	56	84	50	54	37	60	55	67
	64	65	88	40	82	75	52	70	72
Total weight (gram)	827	799	798	745	795	782	744	750	711
Mean	68,92	66,58	66,50	62,08	66,25	65,17	62,00	62,50	59,25
SD	14,164	14,457	13,648	14,419	14,747	13,252	11,004	9,501	8,864

Table 10: The final body weight of 108 individual tilapnia of this experiment (gram)

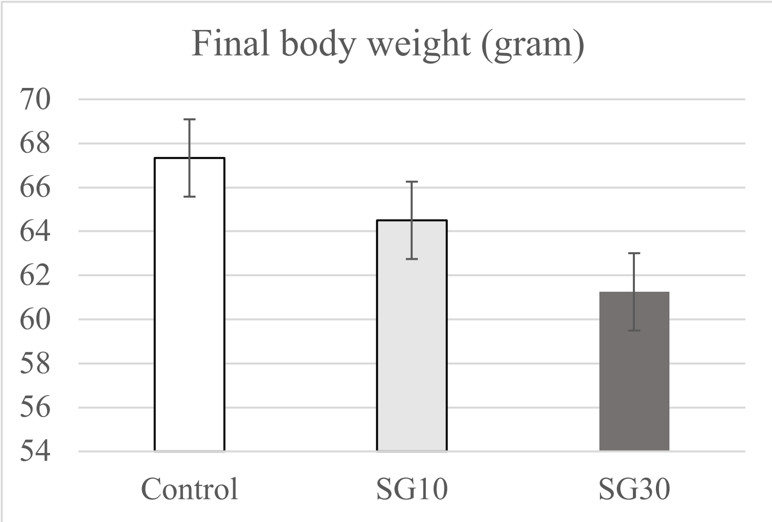

Figure 23: The mean values between of each groups in the final measurement

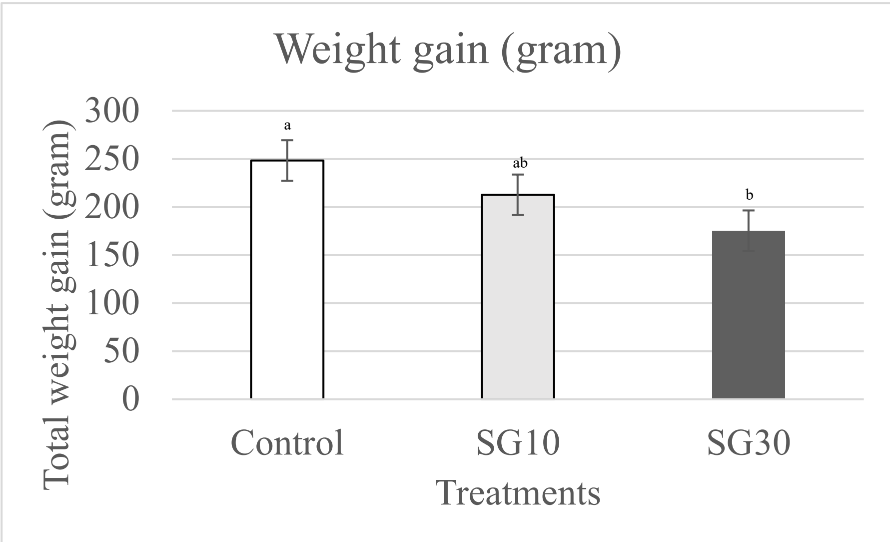

Figure 24: The mean values of total weight gain between of each groups (gram)

Figure 24 shows the comparison of the weight gain (WG) between the control group and the treatment groups, especially 30% slum gum. The results indicate a slightly significant difference between the two groups, with the control group having a higher weight gain (WG=248gr) compared to the treatment group (WG=175gr).

Upon conducting statistical analysis, the comparison between the control and treatment groups yielded a p-value of approximately 0.0048, which is less than the significance level of 0.05. This indicates a statistically significant difference between the two groups, indicating that the treatment with 30% slum gum had a significant effect on the weight gain of the experimental subjects.

Furthermore, when comparing the control group to the groups fed with different percentages of slum gum, all values remained stable, especially when the slum gum was replaced by 10% (SG10) of the diet. In table 11, these findings suggest that the inclusion of slum gum in the diet showed significantly impact the biometric indices studied, except for WG, FCR, PER and SGR. Therefore, slum gum can be safely incorporated into the diet of the fish without adversely affecting their growth and overall health. According to thhe results, using of slum gum in aquatic animal diets may have some potential benefits. Despite the short duration of the experiment, the 100% survival rate across all groups suggests that slum gum might have a impact on feeding.

Slum gum is a complex mixture that contains a variety of compounds, including insect death body, propolis, and carbohydrates. While these compounds may provide some nutritional benefits, they can also pose some challenges for fish digestion or increase moisture levels, which can lead to the development of mycotoxins. Futhermore, the research may be needed to investigate the specific effects of the different diets on the fish’s overall health and development.

	Control	**SG10**	**SG30**	**p-value**
WG (g)	248±8.62a	213±23.44ab	175±16.07b	0.0059
SGR (%/day)	1.31±0.036a	1.15±0.105ab	0.97±0.071b	0.0047
PER (g/g)	1.74±0.044a	1.53±0.146ab	1.26±0.088b	0.0033
FCR (g/g)	1.78±0.045a	2.05±0.208ab	2.44±0.176b	0.0064
CF	0.42±0.024	0.38±0.056	0.33±0.045	0.0883
S%	100	100	100	-

Table 11: The different letters indicate significant differences (ANOVA $p<0.05$) WG: total weight gain, SGR: specific growth rate, PER: protein efficiency ratio, FCR: feed conversion ratio, CF: condion factor, and S: survival rate.

4.2 Growth rate

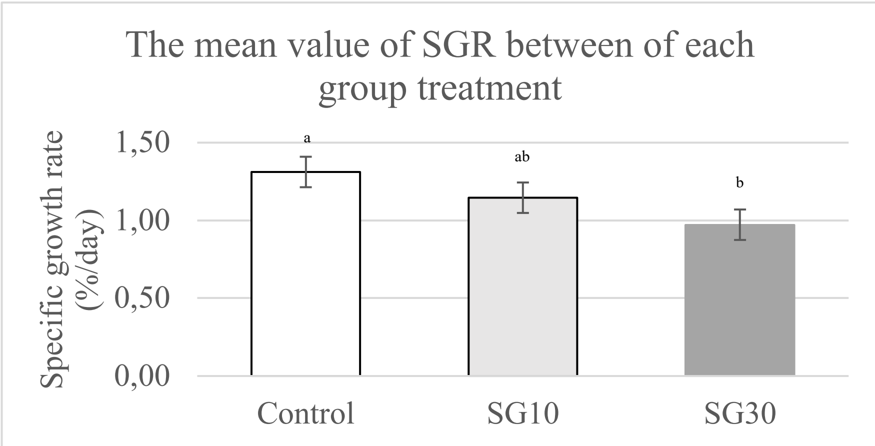

Figure 25: The mean values between of each groups with speciffic growth rate (%/day)

The results of the experiment show that different treatments had an impact on the growth patterns of tilapia, as illustrated in figure 25. The experiment simulated growth patterns during the 4-week timeframe of the study. In figure 26, the treatment with 30% slum gum (SGR = 0,97%) resulted in a slightly significant difference when compared to the control group (SGR = 1,30%), with a p-value of approximately 0.0038, which is less than 0.05.

```
SG10 - Control == 0  0.08328 .
SG30 - Control == 0  0.00356 **
SG30 - SG10 == 0     0.07055 .
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
(Adjusted p values reported -- single-step method)
```

Figure 26: The treatment with 30% slum gum resulted in a slightly significant difference when compared to the control group.

Homogeneity of variance is a crucial assumption when performing an ANOVA, and each group has a comparable level of variation. In figure 27, a red line can be used to provide an approximate representation of the variability trend. In the instance where the fitted values descrease, the variance may vary slightly. This implies that the inclusion of slum gum in the diet of tilapia at a 10% replacement level may be safe and potentially beneficial for improving protein efficiency. This suggests that a high volume of slum gum can have a negative effect on the growth rate of tilapia.

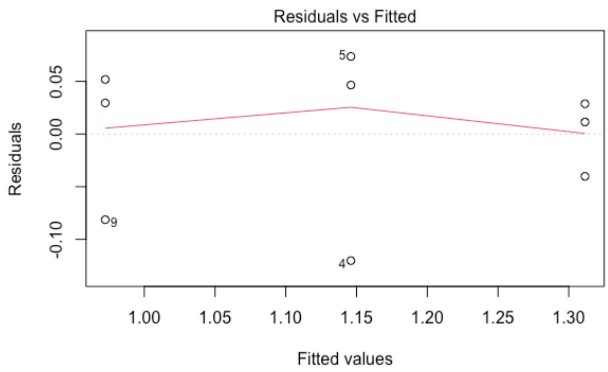

Figure 27: Results from the execution of the ANOVA procedure

4.3 Feed conversion ratio

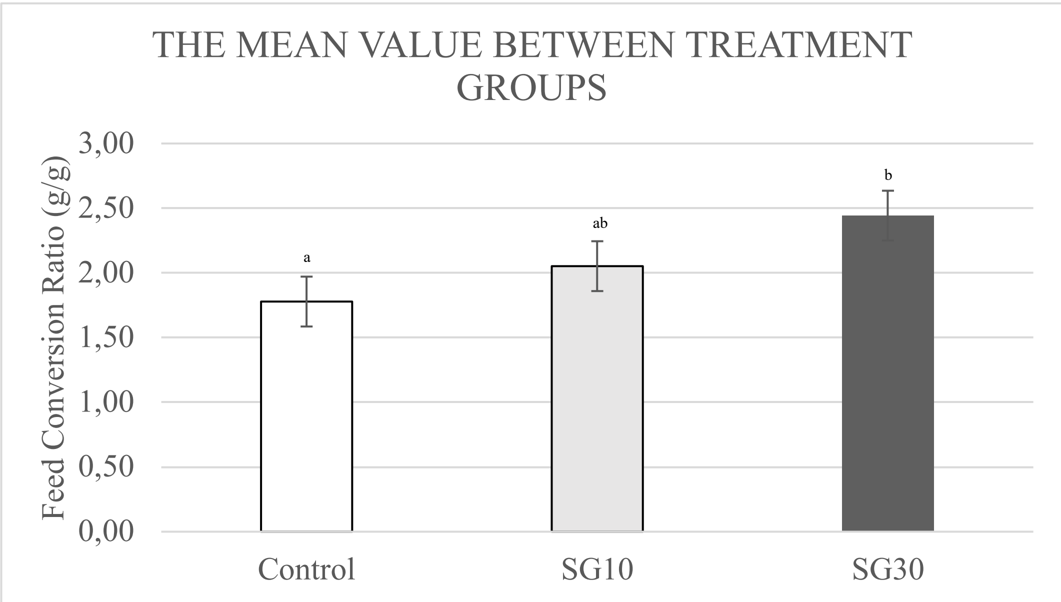

Figure 28: Mean value of feed conversion ratio between of each group (g/g)

Based on the results obtained from figure 28, it can be observed that the feed conversion ratio (FCR) values were more distinct between the control group and the other treatments. The highest FCR values were observed in the SG30 group, while the control group had the lowest values. In the case of the other treatment groups, a significant difference was observed compared to the control group.

When examining the final body weight (FBW) of tilapia, it was found that the control group had the highest body weight (248 ± 8.62), SG30 treatment groups had significantly deviated from this value, even though SG10 (213 ± 23.44) closely approaching the control group. In contrast to the previous chart, the feed conversion ratio (FCR) chart showed a distinct pattern. The FCR of the control group was found to be lower than that of the other groups, indicating a higher feed efficiency in this group. Efficient conversion of feed into fish weight gain is indicated by lower FCR values, whereas overfeeding or underfeeding leads to an increase in the ratio. Upon conducting statistical analysis, significant differences were observed between the different treatment groups, specifically between the control group and SG30.

The statistical analysis revealed a p-value of less than 0.05, indicating a statistically significant difference between the two groups. This finding suggests that the SG30 group had a significantly different FCR compared to the control group, indicating a difference in feed efficiency between the two groups. These results highlight the importance of conducting statistical analysis to determine the significance of differences observed in experimental data.

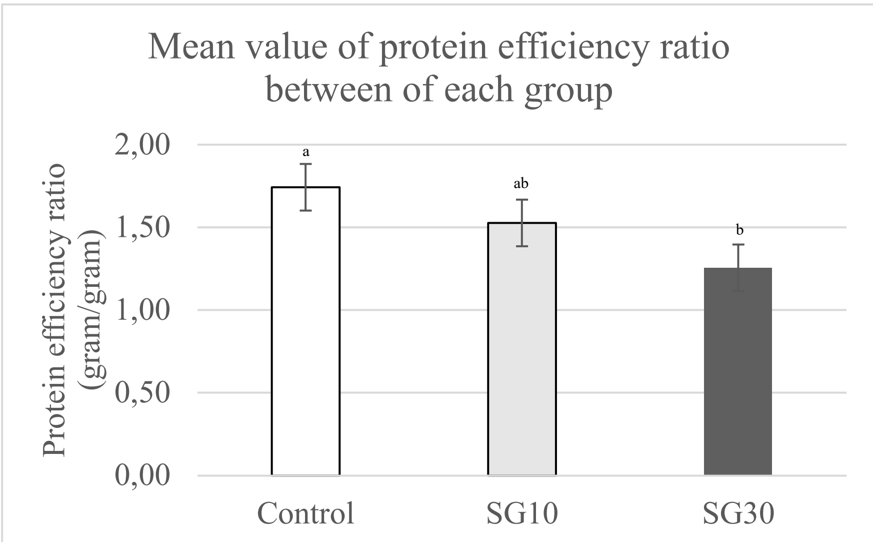

Figure 29: Mean value of protein efficiency ratio between of each group

As presented in figure 29, the p-value indicate that significant differences (p=0.05) were observed in protein efficiency ratio (PER) between the group treated with 30% slum gum and the control group. Despite the crude protein content in each group being closely evaluated, with the control group at 32.28%, SG10 at 32.12%, and SG30 at 32.71%, the average PER after 4 weeks in the SG30 group was approximately 1.26 grams, whereas the control group had an average PER of 1.74 grams.

These findings suggest that replacing 10% of the feed with slum gum may have a positive impact on tilapia, as the PER values in the SG30 group were significantly lower than those in the control group (figure 30).

```
Linear Hypotheses:
Estimate Std. Error t value Pr(>|t|)
SG10 - Control == 0 -0.21562    0.08307  -2.596  0.09048 .
SG30 - Control == 0 -0.48674    0.08307  -5.860  0.00239 **
SG30 - SG10 == 0    -0.27112    0.08307  -3.264  0.03934 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
(Adjusted p values reported -- single-step method)
```

Figure 30: Significant differences ($p > 0.05$) were found between the different groups

Besides, in figure 31, a reasonable visual indication of the trend in variability can be obtained from the red line. In this instance, the variance slightly differed as the fitted values droped down. Alternatively, a formal statistical test can be used to determine whether the variance is significantly different between groups. This implies that the inclusion of slum gum in the diet of tilapia at a 10% replacement level may be safe and potentially beneficial for improving protein efficiency.

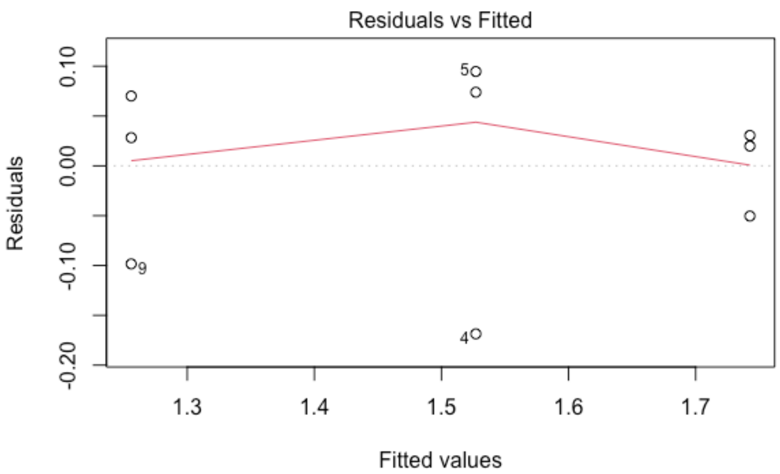

Figure 31: The execution of the ANOVA procedure yielded visible results into the test.

4.3 Condition factor (CF)

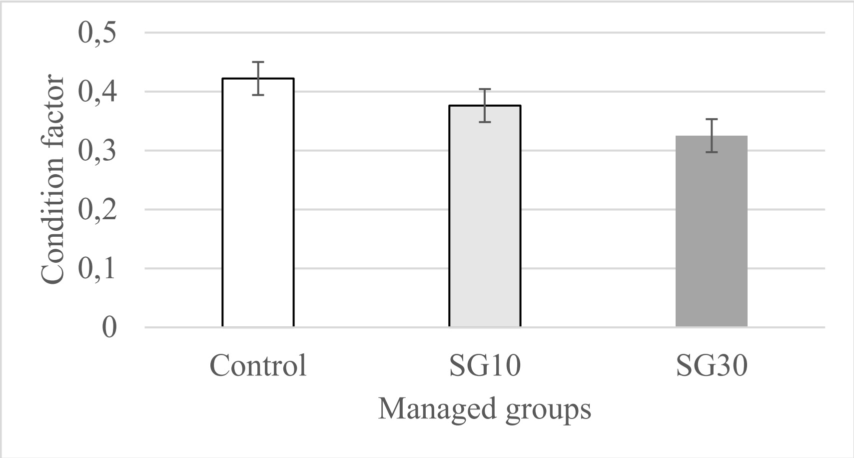

Figure 32: Mean value of condition factor of different treatment groups

According to the results obtained from figure 32, which illustrates the condition factor (CF), it can be observed that the CF values were similar to the total body weight results obtained from the last measurement. The average length increased from 11 cm in the initial week to 12.5 cm in the fourth week in all treatment groups. However, no significant differences were found after the ANOVA test. The CF values of SG30 (0.32) were not significantly different from those of the control group (0.4).

5. Reccomendation

According to the results from the experiment, tilapia fish fed with commercial mixed slum gum have shown significant differences in weight gain, feed conversion ratio, protein efficiency ratio, and specific growth rate between the control group and SG30, but no significant difference between the control group and SG10. In agreement with these results, the concentration of slum gum in fish feed should fluctuate around 10%.

One of the main reasons for this percentage (slum gum to 10%) is the economic value of this approach because it may have significantly affected the materials price, making it a cost-effective solution, as same as reducing the enter prices into raw materials. Additionally, there were not any tests for using 20% of slum gum identified. Besides, using 30% might result in oversupply or wasted feed due to the high concentration of carbohydrates from honey, fatty acids, protein, a part of pollen, nectars, propolis, and complicated chemical compounds contained in slum gum. Therefore, keeping the percentage of slum gum to around 10% ensures a low enter-price, healthy benefits, and reduces the risk of wasting feed. Appearing of slum gum seems to be additive feed to avoid any potential harm to the fish. Slum gum contains complex chemical compounds, which may induce harm to fish in high concentrations. For example, the over-moisture content of slum gum can lead to the growth of fungus, which can convert to mycotoxins, causing significant health problems for the fish. Naturally, the effectiveness of treatments to counteract the effects of fungus growth in slum gum is an important issue.

On top of those results, the different ages and species of fish are also a key consideration when using slum gum as fish feed. This experiment used only tilapia fish, but other tests may give different results for the effects of slum gum on other species as well. The different age groups of fish may respond to dissimilar impacts of slum gum in their diet. Therefore, trying not only one content of slum gum with more research on unlike subjects may determine the most effective and safe percentages in feed.

Another thing needs to focus on the storage conditions of slum gum, which must ensure it remains safe for use in fish feed. The moisture content of slum gum varies and fluctuates depending on the treatment used, and if not stored well, it can lead to the growth of harmful fungus. In this case, the storage duration should be within limits to avoid potential risks, such as in dry, cold, or frozen conditions.

6. Summary

In today's world, while the pressure to produce fish at a higher rate continues to mount, the existing feed resources used in aquaculture are no longer sufficient to meet the increasing demands of the food industry. Moreover, using fishmeal and fish oil as the primary sources of nutrition for farmed fish is becoming increasingly unsustainable due to the environmental costs associated with their production. The production of these resources is becoming scarcer and more expensive, which makes it uneconomical to continue relying on them. Therefore, alternative sources of nutrition, such as by-products, are being investigated to reduce the dependency on traditional feed resources in aquaculture. These alternative sources have the potential to not only maintain fish growth performance but also promote sustainable aquaculture practices, making them a promising avenue for future research in the field.

The Institute of Aquaculture and Environmental Safety at the Kaposvár Campus of the Hungarian University of Agricultural and Life Sciences was the site of the experiment, which utilized 108 self-breeding Nile tilapia fed in 200-liter tanks, with 12 fish per slot. In this study, the purpose would like to investigate the potential benefits of using slum gum as a dietary supplement for Nile tilapia.

The fish were divided into three groups, with the control group receiving commercial tilapia feed for adult fish supplemented with 160g/kg fish meal. The second diet was SG10 containing slum in 10% of the control feed, while the SG30 group had 30% of slumgum and base feed. In a day, the tilapia were fed four times with a dose equivalent to 2.5% of the biomass. The temperature of the water was around 24°C. The weight of the fish was measured at the initial and final term of the four-week experiment.

The results showed significant differences in weight gain, feed conversion ratio, protein efficiency ratio, and specific growth rate between the control group and SG30. In addition, between the control and SG10 was no significance differently. The absence of significant differences among the different treatment groups indicated similar initial measurements, final body weight, condition factor, and survival rates.

There was a 100% survival rate across all groups. Actually, replacing fishmeal with slum gum had some impacts on the growth and general health of Nile tilapia, as evidenced by the statistics results based on weight gain, and feed conversion ratio. Using by-products like slum gum could support more sustainable practices and provide cost-effective solutions for fish feed production, especially 10% slum gum concentration.

In conclusion, incorporating bee by-products, such as slum gum, into fish feed promise alternative feed that can improve growth, economic potential, and others. This alternative can also avoid the waste of more than 1500 tons of slum gum per annum in the EU, promote more sustainable practices, and reduce production costs. Further research is necessary to determine the potential of these by-products for fish feed and investigate their optimal inclusion levels in different fish varieties.

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NGUYEN KIM NGAN

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APPENDICIES

APPENDIX 1

Initial mean body weight

Anova: Single Factor of Initial BW

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	Tukey	
Control (i)	36	1679	46,64	56,64	a	
SG10 (i)	36	1684	46,78	85,38	ab	
SG30 (i)	36	1679	46,64	55,67	b	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,46	2	0,231	0,00351	0,9965	3,0829
Within Groups	6918,83	105	65,894			
Total	6919,30	107				

Q TEST						
group 1	group 2	mean	std err	lower	upper	p-value
Control (i)	SG10 (i)	0,139 a	1,35	-4,41	4,69	0,997
Control (i)	SG30 (i)	0 ab	1,35	-4,55	4,55	1
SG10 (i)	SG30 (i)	0,139 b	1,35	-4,41	4,69	1,0

Final body weight

TUKEY HSD/KRAMER			alpha	0,05		
group	mean	n	ss	Std Err	Lower	Upper
Control	67,3333333	36	6600	2,09469916	63,1799319	71,4867348
SG10	64,5	36	6723	2,09469916	60,3465985	68,6534015
SG30	61,25	36	3262,75	2,09469916	57,0965985	65,4034015
		108	16585,75			

ANOVA					
Sources	*SS*	*df*	*MS*	*F*	*P value*
Between Groups	667,166667	2	333,583333	2,11182792	0,12612785
Within Groups	16585,75	105	157,959524		
Total	17252,9167	107	161,242212		

Q TEST in the final body weight						
group 1	group 2	mean	std err	lower	upper	p-value
Control	SG10	2,83333333	2,09469916	-4,2090452	9,87571189	0,60593635
Control	SG30	6,08333333	2,09469916	-0,9590452	13,1257119	0,10470194
SG10	SG30	3,25	2,09469916	-3,7923786	10,2923786	0,51799689

Weight Gain

TUKEY HSD/KRAMER			alpha		0,05
group	*mean*	*n*	*ss*	*df*	*q-crit*
Control	248	3	148,666667		
SG10	213	3	1098,66667		
SG30	175	3	516,666667		
		9	1764	6	4,339

ANOVA					
Sources	*SS*	*df*	*MS*	*F*	*P value*
Between Groups	7994,89	2	3997,44	13,5967	0,0059
Within Groups	1764	6	294		
Total	9758,89	8	1219,861		

Q TEST						
group 1	group 2	mean	std err	lower	upper	p-value
Control	SG10	35,6667	9,8995	-7,2872	78,6206	0,0961
Control	SG30	73	9,8995	30,0461	115,9539	0,0048
SG10	SG30	37,333333	9,8995	-5,6206	80,2872	0,0826

FCR

TUKEY HSD/KRAMER			alpha	0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Control	1,78	3	0,00413716		
SG10	2,05	3	0,08651209		
SG30	2,44	3	0,06202708		
		9	0,15267634	6	4,339

ANOVA					
Sources	*SS*	*df*	*MS*	*F*	*P value*
Between Groups	0,66807241	2	0,33403621	13,1272288	0,00643701
Within Groups	0,15267634	6	0,02544606		
Total	0,82074875	8	0,10259359		

Q TEST						
group 1	group 2	mean	std err	lower	upper	p-value
Control	SG10	0,27364	0,09210	-0,12597	0,67325	0,16980
Control	SG30	0,66396	0,09210	0,26435	1,06357	0,00534
SG10	SG30	0,39032	0,09210	-0,00929	0,78993	0,05462

	group	mean	sd	n	Tukey
1	Control	1.778437	0.04548166	3	a
2	SG10	2.052079	0.20798088	3	ab
3	SG30	2.442398	0.17610662	3	b

SGR

TUKEY HSD/KRAMER			alpha	0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Control	1,31	3	0,00257271		
SG10	1,15	3	0,02203892		
SG30	0,97	3	0,01017135		
		9	0,03478298	6	4,339

ANOVA					
Sources	*SS*	*df*	*MS*	*F*	*P value*
Between Groups	0,17245918	2	0,08622959	14,8744462	0,00472787
Within Groups	0,03478298	6	0,00579716		
Total	0,20724215	8	0,02590527		

Q TEST							
group 1	group 2	mean	std err	lower	upper	p-value	mean-crit
Control	SG10	0,2	0,0	0,0	0,4	0,083	0,191
Control	SG30	0,3	0,0	0,1	0,5	0,0038	0,19
SG10	SG30	0,2	0,0	0,0	0,4	0,070	0,191

```
Df  Sum Sq Mean Sq F value  Pr(>F)
group        2 0.17246 0.08623   14.87 0.00473 **
Residuals    6 0.03478 0.00580
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Linear Hypotheses:
                 Pr(>|t|)
SG10 - Control == 0  0.08328 .
SG30 - Control == 0  0.00356 **
SG30 - SG10 == 0     0.07055 .
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Adjusted p values reported -- single-step method)
```

PER

TUKEY HSD/KRAMER			alpha	0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Control	1,74	3	0,00386481		
SG10	1,53	3	0,04284762		
SG30	1,26	3	0,01539077		
		9	0,0621032	6	4,339

ANOVA					
Sources	*SS*	*df*	*MS*	*F*	*P value*
Between Groups	0,35692093	2	0,17846046	17,2416678	0,00325555
Within Groups	0,0621032	6	0,01035053		
Total	0,41902413	8	0,05237802		

Q TEST						
group 1	group 2	mean	std err	lower	upper	p-value
Control	SG10	0,21562239	0,05873822	-0,0392427	0,47048751	0,09037577
Control	SG30	0,48674483	0,05873822	0,23187972	0,74160995	0,00264201
SG10	SG30	0,27112244	0,05873822	0,01625733	0,52598756	0,03938335

```
Df Sum Sq Mean Sq F value  Pr(>F)
group       2 0.3569 0.17846   17.24 0.00326 **
Residuals    6 0.0621 0.01035
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Linear Hypotheses:
Estimate Std. Error t value Pr(>|t|)
SG10 - Control == 0 -0.21562    0.08307  -2.596  0.09048 .
SG30 - Control == 0 -0.48674    0.08307  -5.860  0.00239 **
SG30 - SG10 == 0    -0.27112    0.08307  -3.264  0.03934 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
(Adjusted p values reported -- single-step method)
```

CF

TUKEY HSD/KRAMER			alpha	0,05	
group	*mean*	*n*	*ss*	*df*	*q-crit*
Control	0,422179	3	0,0011205		
SG10	0,37623956	3	0,00617346		
SG30	0,32521394	3	0,00403484		
		9	0,0113288	6	4,339

ANOVA					
Sources	*SS*	*df*	*MS*	*F*	*P value*
Between Groups	0,01411627	2	0,00705813	3,738154	0,08825533
Within Groups	0,0113288	6	0,00188813		
Total	0,02544507	8	0,00318063		

Q TEST						
group 1	group 2	mean	std err	lower	upper	p-value
Control	SG10	0,04593944	0,0250874	-0,0629148	0,15479369	0,44785552
Control	SG30	0,09696506	0,0250874	-0,0118892	0,2058193	0,07595655
SG10	SG30	0,05102562	0,0250874	-0,0578286	0,15987986	0,38169581

Appendix 4 – Declaration

DECLARATION

on authenticity and public assess of final mater's thesis

Student's name:	NGUYEN KIM NGAN
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Title of the document:	APPLICATION OF BEEKEEPING BY-PRODUCT (SLUM GUM) IN FISH FEED
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Department:	Department of Farm Animal Nutrition

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ABSTRACT OF THESIS

Thesis title APPLICATION OF BEEKEEPING BY-PRODUCT (SLUM GUM) IN FISH FEED
Author name NGUYEN KIM NGAN

Course, level of education: Animal Nutrition and Feed Safety master program in English
Host Department/Institute: Institute of Aquaculture and Environmental Safety

Primary thesis advisor: Dr. Kucska Balázs, Senior Research Fellow, Institute of Aquaculture and Environmental Safety, Department of Applied Fish Biology

Independent consultant:

The aim of this study was to assess the potential benefits of incorporating by-products in tilapia feed and to investigate whether adding slum gum to the fish feed would enhance the growth rate of Nile tilapia. The impact of slum gum on growth rate was expected to be influenced by the level of supplementation, with a higher concentration potentially leading to better growth rates. The study was conducted over four weeks with 108 Nile tilapia (w=46.6±0.9g) fed diets containing two different levels of slum gum (10% and 30%). The results showed that while the higher concentration of slum gum had a negative impact on growth and feed conversion ratio, no significant differences were observed in the production parameters at the lower level (10%). Thus, incorporating slum gum into tilapia feed could be a beneficial option if done in moderation.

DIPLOMADOLGOZAT/SZAKDOLGOZAT BÍRÁLATI LAP
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I. Témaválasztás / Choice of topic

1. Célkitűzések, logikai ív, koherens gondolatmenet / Objectives, logical and coherent train of thoughts:

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2. Az elméletek, fogalmak, modellek ismerete, alkalmazása / The knowledge and application of theories, concepts and models:

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3. Elemző, értékelő, összehasonlító, kritikai észrevételek / Analytic, evaluative, comparative and critical observations:

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5. A kutatási kérdések/hipotézisek / Stating research questions/hypotheses:

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6. Az adatgyűjtés és adatfeldolgozás módszertana/ The method of data collection and processing:

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7. Elemzőkészség / Analytical skills:

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8. Következtetések és javaslatok / Conclusions and suggestions:

1 2 3 4 5

IV. Formai követelmények / Formal requirements

9. A dolgozat stílusa / The style of the thesis:

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10. A dolgozat struktúrája / The structure of the thesis:

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A bíráló szakmai kérdései / Questions of the thesis referee:

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