IOSUD - "DUNĂREA DE JOS" UNIVERSITY OF GALATI

Doctoral School of Fundamental Sciences and Engineering

DOCTORAL THESIS ABSTRACT

ENTREPRENEURIAL MANAGEMENT IN THE FIELD OF BEEKEEPING INTEGRATED WITH AQUAPONIC SYSTEMS

PhD student,

Constanta Laura AUGUSTIN (ZUGRAVU)

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Series I 9: Engineering and management in agriculture and rural development, Nr. 7

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PhD

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Contents

Keywords:

management, intensive beekeeping, aquaponic system, American mint, fuzzy sensory analysis.

Introduction

The doctoral thesis “Entrepreneurial management in the field of beekeeping integrated with aquaponic systems” is structured in four chapters, the list of papers published during the thesis, bibliography and annexes.

Within the doctoral thesis, the presentation of the experimental data and the graphical representation of the obtained results were made through 48 figures and 51 tables. For documentation, 181 current bibliographic titles were used, carefully selected from the local and international literature, most of the last 10 years, properly cited during the paper.

In the first chapter, entitled "Intensive beekeeping", we analyzed the place, role and importance of Romanian beekeeping at European level. We proudly found that Romanian beekeeping holds the first place in the EU from the perspective of total honey production. However, the level of intensification of production is below the European average, twice lower than the most competitive production systems in Europe, which are found in Finland, Germany and the United Kingdom. This extraordinary economic potential that beekeeping has in Romania contrasts with the lack of competitiveness that manifests itself in the economy as a whole. Through this doctoral thesis, I propose an integrated production model that offers advantages related to the intensification of production in beekeeping and the increase of competitiveness within the agri-food system. Intensive beekeeping integrated with aquaponic systems is a sustainable and extremely profitable economic activity. With small investments for the acquisition of aquaponic microsystems, significant increases in honey and vegetable production are obtained, thus eliminating the impact of climate change. The investments for the acquisition of an integrated aquaponic microsystem are 250 euros. They shall be recovered from the first year provided that the costs of transhumance are eliminated. Reducing transhumance will lead farmers to adopt biodiversity conservation practices to increase wild pollinator populations. With small investments for the acquisition of aquaponic microsystems, significant increases in honey and vegetable production are obtained, thus eliminating the impact of climate change. The investments for the acquisition of an integrated aquaponic microsystem are 250 euros. They shall be recovered from the first year provided that the costs of transhumance are eliminated. Reducing transhumance will lead farmers to adopt biodiversity conservation practices to increase wild pollinator populations. With small investments for the acquisition of aquaponic microsystems, significant increases in honey and vegetable production are obtained, thus eliminating the impact of climate change. The investments for the acquisition of an integrated aquaponic microsystem are 250 euros. They shall be recovered from the first year provided that the costs of transhumance are eliminated. Reducing transhumance will lead farmers to adopt biodiversity conservation practices to increase wild pollinator populations.

Chapter II, called "Intensive beekeeping integrated with the aquaponic system", we addressed the integration of beekeeping with aquaponic systems to capitalize on production processes wastewater from recirculating aquaculture systems that have high concentrations of nitrites. Through nitrifying bacteria, wastewater is transformed into production factors for honey plants used in intensive beekeeping. The main problem of recirculation systems in aquaculture is the production of nitrates rich in waste, the water to be treated and which causes environmental problems. For hydroponic systems, the main problem is the dependence on chemical fertilizers. By integrating these two technologies into aquaponics systems, the environmental problems that each of these technologies generates when operating separately are thus solved. In this doctoral thesis we analyzed the possibility of acclimatization and also the production potential of the American mint Lophanthus Anisatus, in order to introduce it in aquaponic culture systems integrated with intensive beekeeping. The main objectives of integrated beekeeping in aquaponic systems are: the simultaneous integration of technical, economic, ecological, spatial and societal objectives in the development of the model of multifunctional aquaponic production platforms. One of the most important aspects of aquaponics is the design of the system. The technical implementation of the correct type of aquoponic system will determine the success or failure of the business. Given this, the design phase of the aquaponic system is the first step towards a proper implementation process. These intensive systems use water treatment plants to remove toxic products from organic waste from fish as well as uneaten fish feed. Aquaponic systems integrated with intensive beekeeping offer the advantage of disposing of this organic waste by using it as a source of nutrients for honey plants in these systems. This integration solves the environmental problems represented by aquaculture wastewater, reduces total water consumption and also obtains nutrients that are used by honey plants. This synergy of the system represented by integration generates an increase of the economic value that is obtained in each branch of production. The potential profitability of the intensive beekeeping system integrated into aquaponic systems increases due to the use of additional factors of production without generating an increase in production costs that eliminates the negative impact of pollution of environmental resources.

In the third chapter entitled "Research on the quality of products obtained in integrated beekeeping systems" we analyzed the quality of honey obtained from the recovery of American mint,Agastache foeniculum lophanthus, grown in aeroponic systems. Mint honey, obtained in this intensive beekeeping system, allows bees to prolong the harvesting period of the honey plant. Mint honey has a higher concentration of antioxidants, in the form of phenols, compared to other varieties of honey. We used this mint honey in combination with the American mint extract obtained by cold pressing, in order to obtain mint liqueur in a proportion of 1/10 with alcohol. The by-products obtained by cold pressing American mint leaves were used to obtain mint syrup and mint sweetness by boiling in combination with mint honey, lemon and ginger.American mint honey induces a menthol flavor because mint is rich in volatile oils, being considered a tonic product for the nervous system and a strong stimulant for the immune system through the action it has on the digestive system.American mint honey has exceptional qualities, being comparable to royal jelly or manuka honey, in terms of quality and purity. Unlike honey obtained from arboreal flowers, it, like polyfloral honey and honey obtained from the flowers of annual plants, has heavy metals in its composition (according to determinations with specific tests). In the honey obtained from arboreal flowers or perennial plants located near urban areas or roads, we identified high concentrations of heavy metals, due to air pollution in these areas. The antibacterial properties of American mint have been exploited through products such as mint jam or mint liqueur. Although mint honey has these precious qualities,This variety of honey has a greenish color that crystallizes into fine grains. According to the sensory analysis performed on the samples of American mint honey, it is found that it meets all the quality standards provided in the standard.For the fuzzy sensory analysis of the honey samples we used membership functions with triangular distribution. Thus, the linguistic terms of perception with which experts appreciate the sensory characteristics of honey varieties are converted into so-called triplets belonging to three of the values of the scale.The triangular belonging functions were used in this model to assess the degree of belonging to three of the linguistic terms, with different weights.For the development of the fuzzy sensory analysis model of bee honey, we used Matlab R2020b with the help of which we modeled the sensory perceptions in relation to the main quality characteristics of mint honey in relation to the other varieties of honey.The sensory quality index of each honey assortment is obtained by converting qualitative assessments through linguistic terms into a set of 3 numerical values on a sensory scale of assessment of results with 5 linguistic values: unsatisfactory, satisfactory, average, good, excellent . This set of 3 numerical values describes the function of triangular belonging to the five linguistic values. Each of the quality attributes in the sensory analysis has a relative weight in the total quality index. This relative weighting is determined on the basis of the assessments of a set of 20 consumers who provide assessments of the sensory quality of bee honey, as well as based on physico-chemical determinations performed to highlight the quality of honey according to European and national standards. The relative weight that each sensory quality attribute has in the calculation of the global sensory quality index is established with the help of qualitative assessments, based on linguistic terms, using a fuzzy sensory scale.The fuzzy sensory analysis applied for the comparative analysis of American mint honey, shows that this assortment of honey is close in terms of global sensory qualities, acacia honey. These global sensory quality indices were calculated based on the perception of experts in relation to the attributes of sensory quality. The weight of the sensory quality indices of each quality attribute in the calculation of the global sensory quality indices of the honey assortments is also established based on the perception of the experts.

1. Intensive beekeeping

Honey production and honey consumption in European Union (EU) member countries are indicators on which the EU is considered the world's second largest producer of bee products and a major player in the bee market. According to EUROSTAT data[1], EU bee honey production was around 250,000 tonnes in 2018, representing 13.3% of world production. However, EU production has increased slightly over the last ten years (+ 6% compared to 2010), with negative or positive annual variations, depending on climatic and meteorological conditions. European honey production, according to statistics, covers only 60% of the annual needs of European consumers. The consumption of bee honey at European level, represents according to EUROSTAT, approximately 20-25% of the world honey consumption, thus representing an average consumption of 0.70 kilograms per person per year. The EU is thus one of the largest importers of bee honey, with annual imports of bee honey ranging from 120,000 to 150,000 tonnes. The main suppliers of bee honey are China, by 63,900 tonnes (43% of total EU imports), Argentina by 22,300 tonnes, Mexico by 21,200 tonnes and Ukraine by 8,900 tonnes of honey. At the same time, the lower price of bee products from China is a determining factor leading to a decrease in bee honey exports from EU Member States.

Starting from the place and role of European beekeeping, we find that Romania ranks second in the European Union, after Spain, in the number of hives of bee families and in first place in the production of bee honey according to Eurostat[1]. Romania ranked 17th in the world top of bee honey producers with a production of approximately 21 thousand tons.

Figure1.1. American mint of Lophanthus Anisatus species, October 2019

In this doctoral thesis I tried to acclimatize the American mint (Lophanthus Anisatus) and I made experimental lots for its use in aquaponic systems. These lots were located near lots of peppers, cabbage and pumpkins. We found the special resistance of the American mint in relation to the diseases that affected vegetable crops. Moreover, the specific odors generated by volatile oils have been an effective measure of protection against pests (aphids, rodents and others).

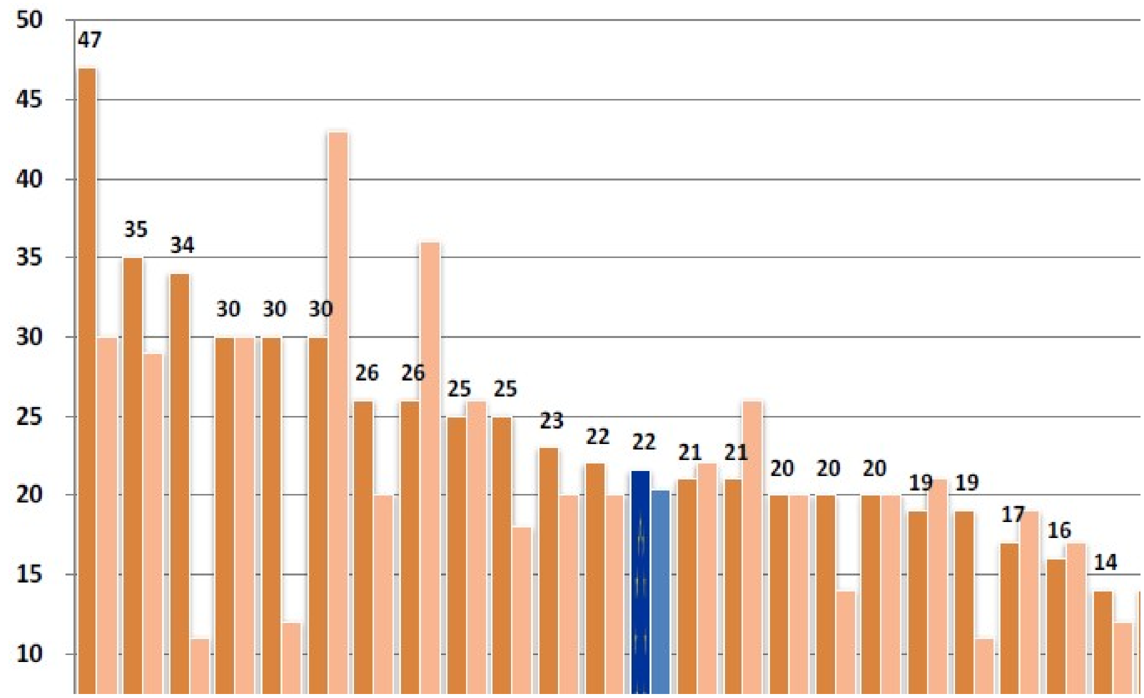

Figure 1.2. Evolution of honey production in kg / hive (Eurostat, 2018).

Regarding the comparison of the level of competitiveness between European beekeepers and their competitors elsewhere, we can say that EU beekeepers face relatively high production costs. These measures to intensify beekeeping by integrating them into aquaponic systems offer the possibility of reducing production costs by increasing the duration of the production cycle by almost 4 times and by reducing fixed production costs which are thus distributed over at least 7 distinct production branches: beekeeping, aquaculture, herbs, volatile oils and plant biomass with high calorific value that can be used for the production of pellets, social apitherapy services, education and health services. Interestingly, this integration of the various industries also offers the advantage of reducing the costs associated with production activities indirectly. Integration actually solves the problems associated or generated by each of these activities if they were developed independently and not within an integrated system.

2. Intensive beekeeping integrated with the aquaponic system

Intensive beekeeping integrated with aquaponic systems is a variant of beekeeping for small farmers that aims to make intensive beekeeping a viable and sustainable economic activity. Intensive beekeeping integrated with aquaponic systems is a variant of high-tech beekeeping.

Aquaponia is a food production system that combines the production of hydroponic vegetables and aquaculture in a closed recycled system. This combination of multi-trophic integrated hydroponics and aquaculture production methods eliminates the problems associated with individual production methods.

Beekeeping integrated with aquaponics is thus a true artificial ecosystem in which we find bees, honey plants, fish, bacteria, worms or other organisms, growing together symbiotically [2] - [4]. The beekeeping system integrated with the aquaponic system uses water more efficiently through the interaction activities of fish, honey plants and bees.

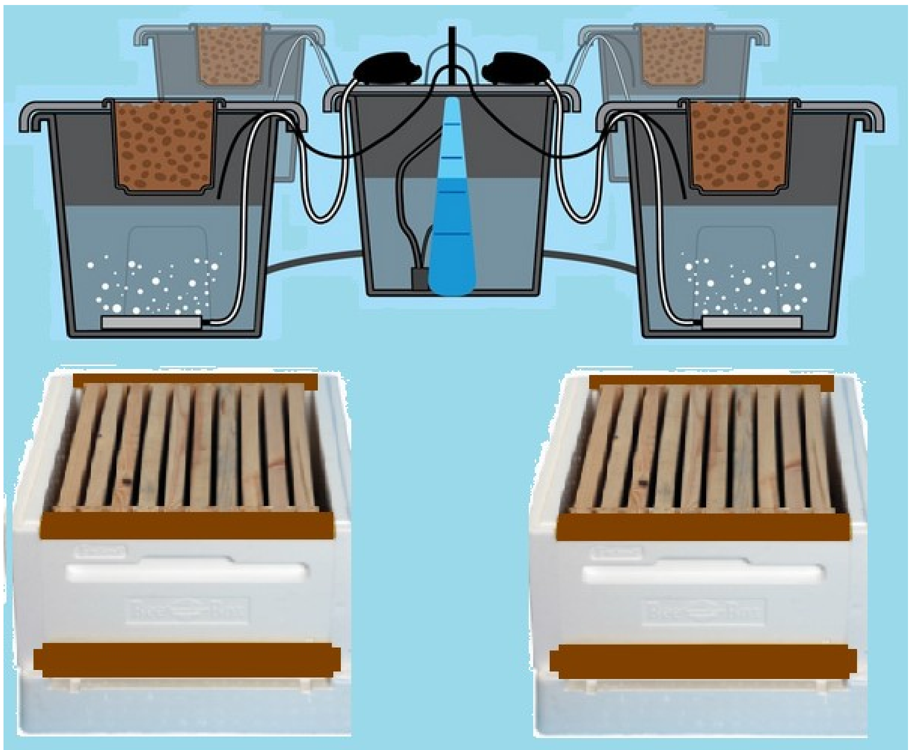

Figure 2.1. Model of aquaponic system integrated with intensive beekeeping.

The model of intensive beekeeping integrated within an aquaponic system shown in fig. 2.1, is a sustainable economic activity that fits very well with the concept of small-scale ecological agricultural development. It is an activity that makes intensive use of existing local resources and can be easily implemented in larger agricultural or aquaculture projects. Bees not only help pollinate crops used in such projects, but use otherwise unused resources: nutrients from wastewater from aquaculture, nectar and pollen.

As integrated bee colony management already exists in most regions of the world, the aim of this doctoral thesis is to develop a more efficient sustainable model. Thus, intensive beekeeping integrated into aquaponic systems is based on the introduction of new, sustainable and more efficient methods in terms of exploitation and exploitation of resources at ecosystem level.

All inputs of production factors necessary for the implementation of such an intensive beekeeping model integrated with aquaponic systems can be made locally, and do not generate any pressure on existing resources. This integration capitalizes on the waste that intensive aquaculture generates, thus providing nutrient resources for honey plants intended for intensive beekeeping. Thus, this sustainable model of intensive beekeeping can create consistent incomes for beekeepers for a longer duration of the production cycle by diversifying the activity in the field of aquaculture and vegetable growing. Against the background of climate change, bee populations suffer significant losses of over 25% due to temperature fluctuations. Bees are influenced by rising temperatures,

Such a small intensive beekeeping project can be profitable from the beginning. After the initial period, as a result of the learning effect, the expertise will be gained, and it will be very easy for a beekeeper to increase the number of hives and the degree of intensification of production. By means of such a model, the dependence on the floral resources of external honey plants is reduced, deficient in the autumn periods. During the winter, when the bees go into hibernation, beekeepers can obtain permanent income by capitalizing on vegetable crops grown in the aquaponic system and also fish production at competitive prices.

The bees that feed on the existing nectar and pollen resources in the area, suffer from their lack in the hot summer periods and in the late autumn periods. Such a model of intensive beekeeping integrated into aquaponic systems thus offers the advantage of consistent nectar and pollen resources that honey plants in aquaponic systems can provide to bees during periods when they are deficient in the external environment, while eliminating transport costs that are much higher in these periods.

Starting from this integration of the 3 productive systems, the objective of the research is to make an analysis of the global efficiency of this production model. We chose as a honey plant for the American mint experiment of Lophantus Anisatus species based on the high productivity potential that it has in relation to other honey plants that can be integrated into an aeroponic production system (Annex 1). Before starting the experiment, the honey plants of the Lophanthus Anisatus species were acclimatized to the specific local climate and soil conditions in Galați County for two years. With the seeds obtained from these plants, seedlings were grown in mini greenhouses. Also, the biological activation of the LECA culture substrate was performed in a recirculating mini-aquaculture system.

The variation of prices during the year for organic plants is quite small both internationally, remaining depending on the seasonality in the range of 17-22 euros per kg of dried leaves. It provides sustainability to integrated aeroponic systems that are implemented to grow Agastache foeniculum lophanthus honey plants for intensive beekeeping.

In aeroponic systems, mint can be harvested throughout the year, unlike open crops, in which the harvesting period takes place during the flowering period, in June-September.

Up to 20 tons of fresh mint leaves can be obtained from 1 ha grown with mint in an open system. This green vegetable mass turns into 2-3 tons of dried mint[5] - [7]. Planting a ha of open-pit mint amounts to planting material costs and planting and maintaining the crop for 5,000 to 6,000 euros. One kg of dried mint leaves on the local market sells for 30 lei, so an average profit of 10,000 euros per year can be obtained per hectare. Proper storage and drying in ventilated and dark areas determines the quality and selling price[8] - [10].

At the same time, this plant has a special beekeeping importance, in North America being considered one of the most important plants for pollinators, being visited by wild bees, honey bees, butterflies, bumblebees and other pollinators. It is estimated that half a hectare cultivated with this honey plant can support over 100 bee families, and aniseed-flavored honey is highly valued by Americans.[11].

In Europe, this honey plant was introduced by beekeepers. In some regions of Europe (even in Hungary), this plant grows wild in its spontaneous flora. In our country, Lophanthus anisatus was studied at the Buzău Vegetable Products Research and Development Station, where in 2015 we obtained varieties of seeds acclimatized to the specific climate and soil conditions in our country. Thus, following the research carried out at the vegetable resort in Buzău, a honey potential of 500 kg of honey per ha and a vegetal production of 22 tons of vegetal mass were estimated, under the conditions of a need of 250-350 m3 of water per ha.[8]. We did not find data from beekeepers about its honey potential in our country, most beekeepers prefer spontaneous flora. An economically viable aeroponic model of intensive beekeeping could be an economic motivation that would arouse beekeepers' interest in this honey plant, given that 1 kg of such honey is sold on the US market for $ 100. Lophanthus anisatus has a high resistance to diseases and pests, the pH of the substrate is recommended to be 6 - 6.5. We found that Lophantus anisatus is resistant to low winter temperatures. The plant enters the vegetation since winter on the background of global warming.

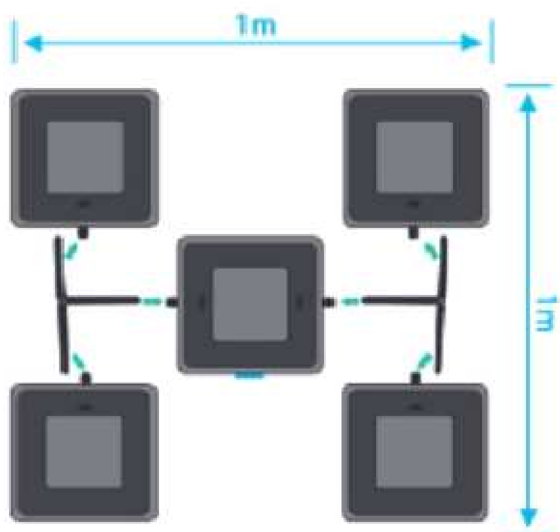

Figure 2. 2 Configuration of aeroponic modules for growing honey plants

At the base of each aeroponic growth module is positioned an aquarium stone that is connected to an air pump (figure 2.5).

Figure 2. 3 Aeration system in the aeroponic growth module.

The total volume of the entire aeroponic system is 180 l. It is recirculated in the aeroponic culture modules with the help of a 7 W pump with a flow rate of 600 liters / h. This pump provides the necessary nutrients for the growth and development of honey plants. These nutrients are taken from the Japanese Koi carp breeding tank and are brought to the roots of the plants, using the NFT culture technique. The DWC cultivation technique is ensured by means of the high water level that covers the roots of the honey plants. The aeroponic culture technique ensures a continuous flow by means of air pumps that ensure a flow of 4 l / min in each growth module (figure 2.6).

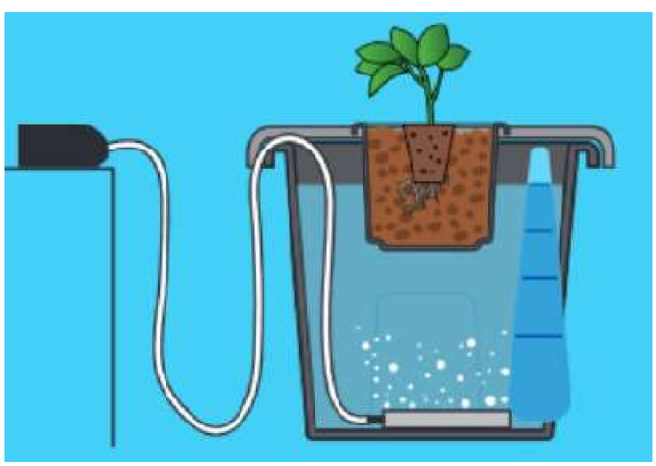

Figure 2. 4 Aeroponic culture technique

Also, the location of the intensive beekeeping system integrated with the aeroponic system is a very important decision. A semi-open system offers both the advantage of limiting exposure to climatic elements and the benefits of direct exposure of honey plants to sunlight.The decision to locate the aeroponic system, analyzes the advantages and disadvantages of indoor or outdoor variants. An aeroponic system located inside, controls environmental factors more easily but involves higher costs. Outdoor location is the cheapest, but it induces risks related to environmental problems.

In the integrated system used for mint cultivation of the species Lophanthus anisatus for 30 days I used only aeroponic technology for growing and developing mint seedlings.

Figure 2. 5 Mint of Lophanthus anisatus after 5 days of introduction into the aeroponic system.

Aeroponic technology was thus the only resource that provided the nutritional elements necessary for the growth and development of mint seedlings of the species Lophanthus anisatus, to the flowering stage of the plant. The growth rate was higher in the first 5 days after the introduction of mint seedlings in the aeroponic system even if it was not coupled with the recirculating aquaculture system and did not benefit from the nutrients provided by the fish (figure 2.10). With the help of this aeroponic technology without using other nutrient inputs, Lophanthus anisatus mint seedlings increased in 30 days 50 cm in height from the first leaf stage to the seventh floor (Figure 2.11). After 30 days, the Japanese ornamental koi carp was introduced into the aeroponic system (figure 2.12).

Figure 2. 6 Mint of Lophanthus anisatus species grown in the aeroponic system for 30 days

Figure 2. 7 Mint of Lophanthus anisatus species grown in the aeroponic system for 30 days, compared to plants grown in soil.

Mint seedlings were planted in the burnt clay substrate of the aeroponic system in early May. Prolonged drought in winter and spring of 2020 with large temperature variations from day to night, air humidity of 30%, led to a delay in the growth and development of plants grown in soil.

3. Research on the quality of products obtained in integrated beekeeping systems

Romania is the largest producer of bee honey in the European Union, but in terms of average consumption is 500-600 g / capita per year, which is three times lower than the European average.

In this doctoral thesis I studied the possibility of introducing American mint in intensive beekeeping,Agastache foeniculum lophanthus, grown in aeroponic systems. Mint honey, obtained in this intensive beekeeping system, allows bees to extend the harvesting period of the honey plant. Mint honey has a higher concentration of antioxidants, in the form of phenols, compared to other varieties of honey. We used this mint honey in combination with the American mint extract obtained by cold pressing, in order to obtain mint liqueur in a proportion of 1/10 with alcohol. By-products obtained by cold pressing of American mint leaves were used to obtain mint syrup and mint sweetness by boiling in combination with lemon honey, lemon and ginger.

The price of bee honey is in a direct correlation with its quality, because obtaining honey is a complex process that requires a consumption of resources, in which the largest share is the logistical transport costs involved in transhumance.

Table 3. 1 Determination of water percentages, Brix degrees and Baume degrees on the optical refractometer scale for the comparative analysis of honey assortments

Nr. Crt.	Assortment of honey	Grade Baume	Grade Brix	% the water
1.	Mint Honey (2020)	43	81.5	17
2.	Mint Honey (2019)	42	79	19
3.	Izma honey	43	81.5	16.8
4.	Acacia honey (2020)	43	81.5	16.8
5.	Acacia honey (2019)	43.5	82	16
6.	Lime honey	43.2	82	16.5
7.	Lavender honey	43.2	81.5	16.6
8.	Mana honey	43	81.5	17
9.	Polyfloral honey (2020)	43	81.2	17
10.	Polyfloral honey (2019)	41.8	78.5	19.5
11.	Rapeseed honey	43	81	17
12.	Lime honey + manna	43	81.5	17
13.	Sunflower honey	42	79	19.5
14.	Mother bee milk	43.2	81.5	16.5

Source: Determinations using optical refractometer for honey, with thermal compensation - model RHB - 90 (92) T ATC

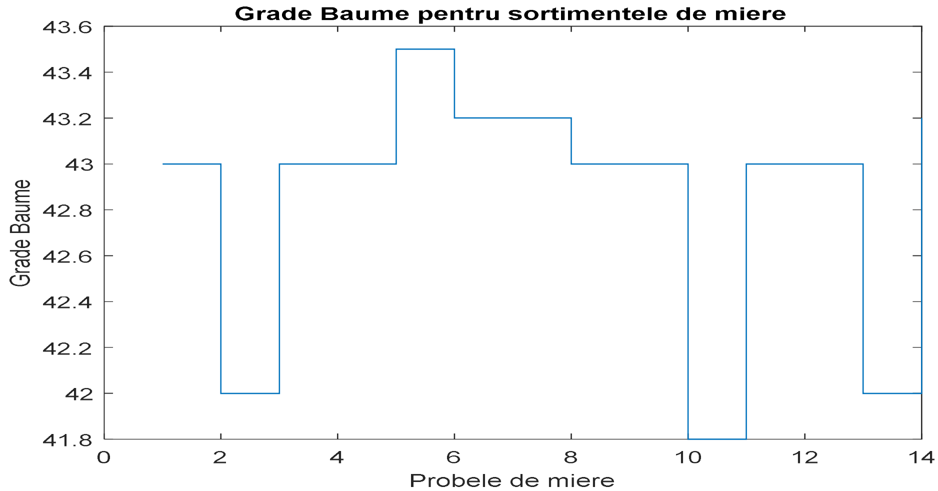

Figure 3. 1 Graphic representation of Baume Degrees for the analyzed honey assortments

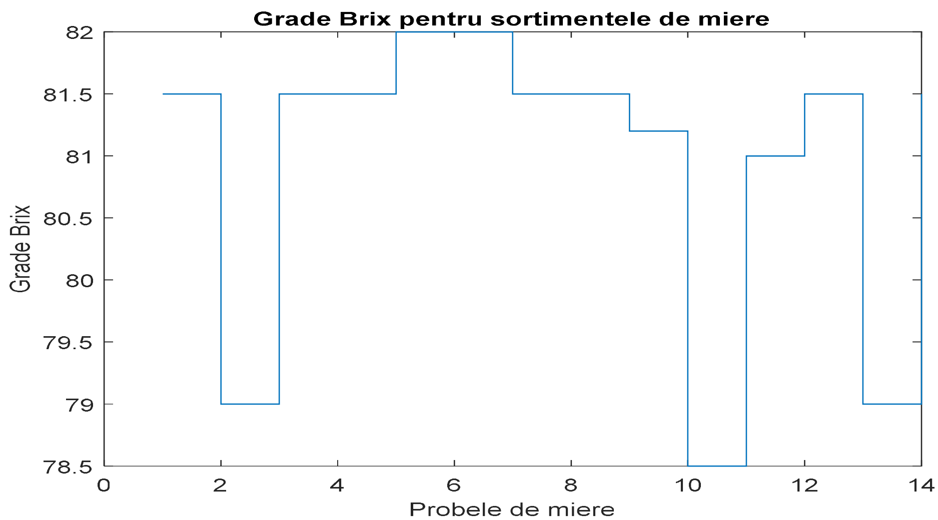

Figure 3.11: Graphical representation of Brix grade determinations for honey varieties

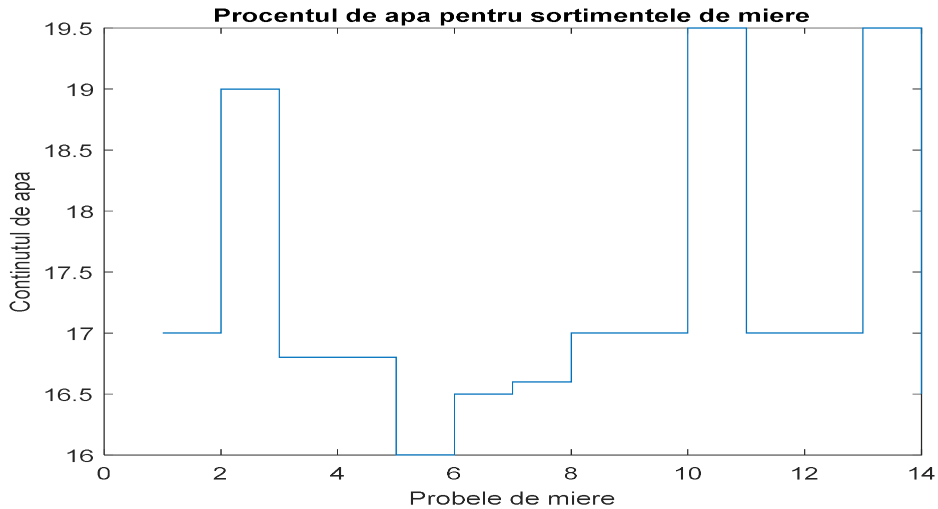

Figure 3. 2 Graphical representation of the water content determinations of the analyzed honey varieties

Sensory analysis, a method of assessing the quality of honey

The concept of quality of a food product sums up all the characteristics, which satisfy the needs of consumers. From this perspective, sensory analysis is considered as a component part of the concept of quality.

Objective testing is based on the determination of sensory properties performed by a group of trained experts, while subjective testing is based on consumer reactions to sensory properties[12], [13].

The values of sensory perception are qualitative evaluations represented by linguistic terms with which experts assess the taste, aroma, color, consistency and appearance of honey. The results recorded for these characteristics regarding the sensory quality of food products can be:

- unsatisfactory,
- satisfying,
- medium,
- good,
- excellent.

These linguistic terms used for the qualitative assessment of sensory attributes (color, aroma, taste, smell and general appearance) are transformed into triplets of numerical values using the membership functions. Thus, the quality of a sensory attribute is assessed using fuzzy logic (working with values between 0 and 1) through three numerical values (on a scale from 0 to 100), which reflects the share of belonging to three of the five values. linguistic.

For example, if the experts' assessment of color is represented by the linguistic term "good", using a triangular affiliation function (Figure 3.15), this linguistic value is associated with a triplet (75 25 25) which reflects the fact that, in the case of color of the honey sample, it belongs to:

- the linguistic term "good" with a weight of 75% of the maximum fuzzy value 1;

- the linguistic term "average" with a weight of 25% of the maximum fuzzy value 1;

- the linguistic term "excellent" with a weight of 25% of the maximum fuzzy value 1.

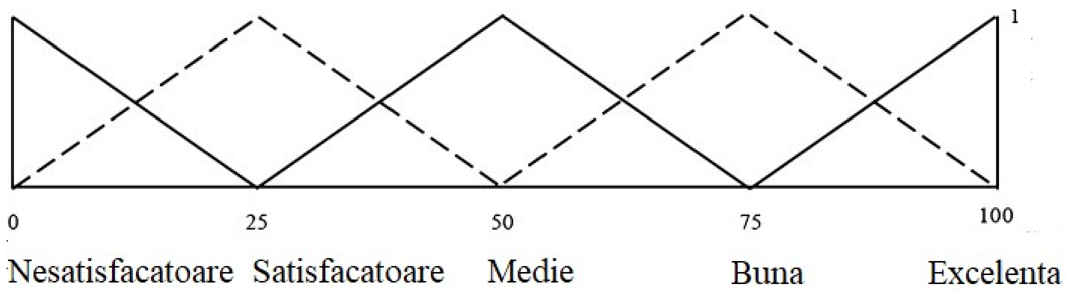

Figure 3. 3 The triangular distribution model of the membership function

For the fuzzy sensory analysis of the honey samples we used membership functions with triangular distribution. Thus, the linguistic terms of perception with which experts appreciate the sensory characteristics of honey varieties are converted into so-called triplets belonging to three of the values of the scale.

The triangular belonging functions were used in this model to assess the degree of belonging to three of the linguistic terms, with different weights.

To develop the model of fuzzy sensory analysis of bee honey, we used Matlab R2020b which offers through its toolkit, the Fuzzy Logic Designer application with which we can model sensory perceptions in relation to the main quality characteristics of mint honey in relation with the other varieties of honey[14] - [16].

The sensory quality index of each honey assortment is obtained by converting qualitative assessments through linguistic terms into a set of 3 numerical values on a sensory scale of assessment of results with 5 linguistic values: unsatisfactory, satisfactory, average, good, excellent (Table 3.28).

Table 3. 2 Numerical triplets associated with a fuzzy sensory scale with five linguistic terms for the qualitative evaluation of each sensory attribute

Unsatisfying	Satisfying	Average	Hi	excellency
0 0 25	25 25 25	50 25 25	75 25 25	100 25 0

This set of 3 numerical values describes the function of triangular belonging to the five linguistic values. Each of the quality attributes in the sensory analysis has a relative weight in the total quality index. This relative weight is established on the basis of assessments of a set of 20 consumers who provide assessments on the sensory quality of bee honey, as well as on the basis of physico-chemical determinations performed to highlight the quality of honey according to European and national standards. The relative weight that each sensory quality attribute has in the calculation of the global sensory quality index is established using qualitative assessments, based on linguistic terms, using a fuzzy sensory scale with the following five linguistic values (Table 3.29):

Table 3. 3 Numerical triplets associated with a fuzzy sensory scale with five linguistic terms for evaluating the relative weight that each sensory attribute has in the calculation of the global sensory quality index

Unimportant	**Unimportant**	**Important**	**Very important**	**Extremely important**
0 0 25	25 25 25	50 25 25	75 25 25	100 25 0

Thus, for the color of honey, the relative weight of this attribute in the calculation of the total quality index, is calculated:

QCrel = QC / Qt;

Where, QCrel is the relative weight of the color quality index (QC) in the total amount of quality quantity weights (Qt)

For the honey flavor, the relative weight of this attribute in the calculation of the total quality index, is calculated:

QArel = QA / Qt;

Where, QArel is the relative weight of the flavor quality index (QA) in the total sum of the quality quantity weights (Qt).

For the taste of honey, the relative weight of this attribute in the calculation of the total quality index, is calculated:

QGrel = HQ / Qt;

Where, QGrel is the relative weight of the quality index on taste (HQ) in the total sum of the weights of quality quantities (Qt).

For the consistency (texture) of bee honey, the relative weight of this attribute in the calculation of the total quality index, is calculated:

QTrel = QT / Qt;

Where, QTrel is the relative weight of the consistency quality index (QT) in the total amount of quality quantity weights (Qt).

For the overall look of honey, the relative weight of this attribute in the calculation of the total quality index, is calculated:

QOrel = QO / Qt;

Where: QOrel is the relative weight of the overall appearance quality index (QO) in the total amount of quality quantity weights (Qt).

Qt is calculated as the sum of the first values in the triplets QC, QA, QG, QT and QO with which the sensory quality is evaluated through the functions of belonging to the linguistic values by consumers.

The quality of each attribute of the sensory analysis CC, CA, CG, CT and CO is calculated based on the assessments of 20 consumers who participated in this sensory analysis and who made qualitative assessments using linguistic terms (unsatisfactory, satisfactory, average, good, excellent). These linguistic values are transformed into triplets of numerical values with the help of the functions belonging to three of the linguistic terms.

This set of three numerical values that is used to reflect quality for each sensory attribute, in the comparative assessment of bee honey samples, were used to obtain a global sensory quality index (CS) that sums the products between the calculated sensory triplets. for each of the quality attributes with the relative weight of each attribute:

$$CS = CC \times QCrel + CA \times QArel + CG \times QGrel + CT \times QTrel + CO \times QOrel, \quad (3.1)$$

Where:

CC - the set of three numerical values of color belonging to three of the 5 linguistic terms of the quality assessment scale,

CA - the set of three numerical values of the aroma belonging to three of the 5 linguistic terms of the quality assessment scale,

CG - the set of three numerical values of taste belonging to three of the 5 linguistic terms of the quality assessment scale,

CT - the set of three numerical values of belonging of the consistency (texture) to three of the 5 linguistic terms of the quality assessment scale,

CO - the set of three numerical values of belonging of the general aspect to three of the 5 linguistic terms of the quality assessment scale,

Table 3. 4 The share of sensory quality attributes in the calculation of the global sensory quality index of honey varieties

Sensory quality attributes	Unimportant	Unimportant	Important	Very important	Extremely important
color	0	0	6	8	6
Flavor	0	0	3	11	6
The taste	0	0	4	10	6
Texture	0	0	6	8	6
Appearance	0	0	6	7	7

Source: Evaluations of a group of 20 experts used for the comparative sensory analysis of American mint honey in relation to the main varieties of honey.

Table 3. 5 Calculation of triplets associated with the share of sensory quality attributes in the calculation of the global sensory quality index of honey varieties

Sensory quality attributes	Calculation of the set of numerical values associated with quality attributes, in Matlab	Triplets associated with quality attributes
color	QC = (0 * [0 0 25] + 0 * [25 25 25] + 6 * [50 25 25] + 8 * [75 25 25] + 6 * [100 25 0]) / 20	75 25 17.5
Flavor	QA = (0 * [0 0 25] + 0 * [25 25 25] + 3 * [50 25 25] + 11 * [75 25 25] + 6 * [100 25 0]) / 20	78.75 25 17.5
The taste	HQ = (0 * [0 0 25] + 0 * [25 25 25] + 4 * [50 25 25] + 10 * [75 25 25] + 6 * [100 25 0]) / 20	77.5 25 17.5
Texture	QT = (0 * [0 0 25] + 0 * [25 25 25] + 6 * [50 25 25] + 8 * [75 25 25] + 6 * [100 25 0]) / 20	75 25 17.5
Appearance	QO = (0 * [0 0 25] + 0 * [25 25 25] + 6 * [50 25 25] + 7 * [75 25 25] + 7 * [100 25 0]) / 20	76.25 25 16.25
	Qt = QC (1) +QA (1) + QG (1) + QT (1) + QO (1);	382.5

Source: Determinations using the Matlab application of the weight of quality attributes in the calculation of the global quality index of American mint honey in relation to the main varieties of honey (Annex 2).

Qt = 75 + 78.75 + 77.5 + 75 + 76.25 = 382.5;

Table 3. 6 Calculation of the relative weight of sensory quality attributes in the calculation of the global sensory quality index of honey varieties

Sensory quality attributes	Calculation of the set of numerical values associated with quality attributes, in Matlab	Triplets associated with quality attributes
color	QCrel = QC / Qt	0.1961 0.0654 0.0458
Flavor	QArel = QA / Qt	0.2059 0.0654 0.0458
The taste	QGrel = HQ / Qt	0.2026 0.0654 0.0458
Texture	QTrel = QT / Qt	0.1961 0.0654 0.0458
Appearance	QOrel = QO / Qt	0.1993 0.0654 0.0425

Source: Determinations using the Matlab application of the weight of quality attributes in the calculation of the global quality index of American mint honey in relation to the main varieties of honey (Annex 2).

The following relationship is used to calculate the global sensory quality indices of honey varieties:

CS = CC ⊗ QCrel ⊕ THAT ⊗ QArel ⊕ Points ⊗ QGrel ⊕ CT ⊗ QTrel ⊕ q O- ⊗ QOrel (3.2);

For the calculation of the global sensory quality indices of the honey assortments, the relation (3.2) is used, in which we have a series of operations of vector multiplication, addition and extended product with fuzzy numbers (triplets) of SD type. The fuzzy SD triplet contains the values assigned for 3 linguistic terms (the one at the top of the triangle, on the left S, and on the right D).

A fuzzy number is of type SD when there are membership functions S (for left), D (for right). The triplet being a scalar quantity (a, b, c), b> 0, c> 0 its membership function is shown in figure 3.16, 3.17, 3. 18:

$$\mu(x) = \begin{cases} \mathrm{S}\left(\dfrac{a-x}{b}\right) & \text{for } x \leqslant a \\ \mathrm{D}\left(\dfrac{x-a}{c}\right) & \text{for } x \geqslant a \end{cases}$$

Figure 3. 4 Expression of the fuzzy triangular belonging function of type SD.

The description of the function of belonging to the linguistic terms by means of the triangular fuzzy sizes of type SD defined by means of triplets (abc) has the following expression:

$$\mu(x) = \begin{cases} 0 & \text{if } x \leqslant a-b \\ \dfrac{x-a+b}{b} & \text{if } a-b \leqslant x \leqslant a \\ \dfrac{a+c-x}{c} & \text{if } a \leqslant x \leqslant a+c \\ 0 & \text{if } a+c \leqslant x \end{cases}$$

Figure 3. 5 SD type fuzzy triangular membership function.

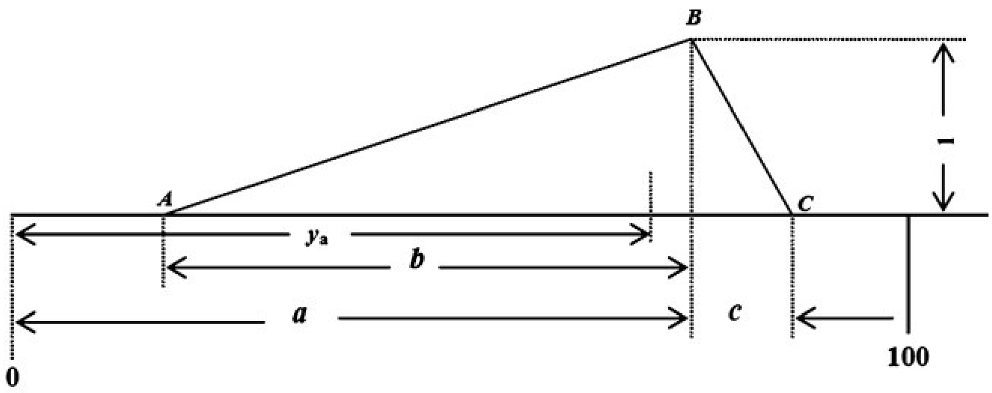

Figure 3. 6 Graphic representation of sensory perception through the fuzzy triplet (a, b, c).

The algebraic operations with fuzzy sizes of SD type used in the sensory analysis model of the quality of mint varieties are:

k (a, b, c) = (ka, kb, kc); (3.3)

(a B C) ⊕(d, e, f) = (a + d, b + e, c + f); (3.4)

(a B C) ⊗(d, e, f) = (ad, ae + db, af + dc); (3.5)

to a, b, c> 0.

We used these operations with fuzzy triplets for the calculation of the global indices of the sensory quality of the honey assortments analyzed through a function created in Matlab, initiated on.m (Annex 3):

% extended product

function C = on (A, B)

C (1) = A (1) * B (1);

C (2) = A (1) * B (2) + B (1) * A (2);

C (3) = A (1) * B (3) + B (1) * A (3);

Table 3. 7 Global indices of sensory quality of honey varieties

Assortments of honey	Calculation of the set of numerical values associated with the color of the honey sample, in Matlab	The value of the triplet associated with the global index of sensory quality
Mint Honey (2020)	CS1 = pe (CC1, QCrel) + pe (CA1, QArel) + pe (CG1, QGrel) + pe (CT1, QTrel) + pe (CO1, QOrel);	75.0163 49.5098 36.9118

Mint Honey (2019)	CS2 = pe (CC2, QCrel) + pe (CA2, QArel) + pe (CG2, QGrel) + pe (CT2, QTrel) + pe (CO2, QOrel);	72.0343 48.5294 37.9820
Izma honey	CS3 = pe (CC3, QCrel) + pe (CA3, QArel) + pe (CG3, QGrel) + pe (CT3, QTrel) + pe (CO3, QOrel);	72.5204 48.4436 37.1078
Acacia honey (2020)	CS4 = pe (CC4, QCrel) + pe (CA4, QArel) + pe (CG4, QGrel) + pe (CT4, QTrel) + pe (CO4, QOrel);	75.4779 49.6732 37.2958
Acacia honey (2019)	CS5 = pe (CC5, QCrel) + pe (CA5, QArel) + pe (CG5, QGrel) + pe (CT5, QTrel) + pe (CO5, QOrel);	74.2320 49.2647 37.7614
Lime honey	CS6 = pe (CC6, QCrel) + pe (CA6, QArel) + pe (CG6, QGrel) + pe (CT6, QTrel) + pe (CO6, QOrel);	73.7582 49.1013 36.8913
Lavender honey	CS7 = pe (CC7, QCrel) + pe (CA7, QArel) + pe (CG7, QGrel) + pe (CT7, QTrel) + pe (CO7, QOrel);	73.7949 49.1013 37.6348
Mana honey	CS8 = pe (CC8, QCrel) + pe (CA8, QArel) + pe (CG8, QGrel) + pe (CT8, QTrel) + pe (CO8, QOrel);	67.2835 46.9771 37.9208
Polyfloral honey (2020)	CS9 = pe (CC9, QCrel) + pe (CA9, QArel) + pe (CG9, QGrel) + pe (CT9, QTrel) + pe (CO9, QOrel);	71.4869 48.3660 37.3856
Polyfloral honey (2019)	CS10 = pe (CC10, QCrel) + pe (CA10, QArel) + pe (CG10, QGrel) + pe (CT10, QTrel) + pe (CO10, QOrel);	68,9706 47,5490 38,0760
Rapeseed honey	CS11 = pe (CC11, QCrel) + pe (CA11, QArel) + pe (CG11, QGrel) + pe (CT11, QTrel) + pe (CO11, QOrel);	68.4967 47.3856 37.7083
Lime honey + manna honey	CS12 = pe (CC12, QCrel) + pe (CA12, QArel) + pe (CG12, QGrel) + pe (CT12, QTrel) + pe (CO12, QOrel);	70.7435 48.1209 37.7206
Sunflower honey	CS13 = pe (CC13, QCrel) + pe (CA13, QArel) + pe (CG13, QGrel) + pe (CT13, QTrel) + pe (CO13, QOrel);	71.4788 48.3660 37.6348
Mother bee milk	CS14 = pe (CC14, QCrel) + pe (CA14, QArel) + pe (CG14, QGrel) + pe (CT14, QTrel) + pe (CO14, QOrel);	70,277 47,9575 37,8391

Source: Determinations using the Matlab application of global sensory quality indices for honey varieties (Annex 2, 3).

For the defuzzification of the global sensory quality indices we used a function created in Matlab entitled df.m (Annex 3):

```
% defuzzification

 function Y = df (A)

Y = (3 * A (1) -A (2) + A (3)) / 3
```

In order to order the global sensory quality indices of the honey assortments, obtained after defuzzification and to determine the position in this comparative analysis, the following relations are used in Matlab:

CS = [df (CS1) df (CS2) df (CS3) df (CS4) df (CS5) df (CS6) df (CS7) df (CS8) df (CS9) df (CS10) df (CS11) df (CS12)) df (CS13) df (CS14)];

[CSd, Ld] = sortrows (CS ', - 1);

[La, L] = sortrows (Ld);

Table 3. 8 The place obtained by the honey assortments in the comparative analysis based on the Global Sensory Quality Indices

The value associated with the global index of sensory quality, CS	The value associated with the global index of sensory quality, in descending order, CSd	Initial position in the comparative analysis, Ld
CS1 = 70.8170	71.3521	4
CS2 = 68.5185	70.8170	1
CS3 = 68.7418	70.3976	5
CS4 = 71.3521	69.9728	7
CS5 = 70.3976	69,682	6
CS6 = 69.6882	68.7418	3
CS7 = 69.9728	68.5185	2
CS8 = 64.2647	67.9017	13
CS9 = 67.8268	67,8268	9
CS10 = 65.8129	67.2767	12
CS11 = 65.2710	66.9050	14
CS12 = 67.2767	65,8129	10
CS13 = 67.9017	65.2710	11
CS14 = 66.9050	64.2647	8

Source: Determinations using the Matlab application of the initial position that the honey assortments had the comparative analysis based on the global indices of comparative sensory quality of the American mint honey in relation to the main honey assortments.

Table 3. 9 The place obtained in the comparative sensory analysis, based on the global indices of sensory quality of the honey assortments

Assortments of honey	The place obtained in the comparative sensory analysis, L	The value associated with the global sensory quality index
Mint Honey (2020)	2	CS1 = 70.8170
Mint Honey (2019)	7	CS2 = 68.5185
Izma honey	6	CS3 = 68.7418

Acacia honey (2020)	1	CS4 = 71.3521
Acacia honey (2019)	3	CS5 = 70.3976
Lime honey	5	CS6 = 69.6882
Lavender honey	4	CS7 = 69.9728
Mana honey	14	CS8 = 64.2647
Polyfloral honey (2020)	9	CS9 = 67.8268
Polyfloral honey (2019)	12	CS10 = 65.8129
Rapeseed honey	13	CS11 = 65.2710
Lime honey + manna honey	10	CS12 = 67.2767
Sunflower honey	8	CS13 = 67.9017
Mother bee milk	11	CS14 = 66.9050

Source: Determinations using the Matlab application of the place obtained in the comparative sensory analysis, based on the global sensory quality indices for the honey assortments.

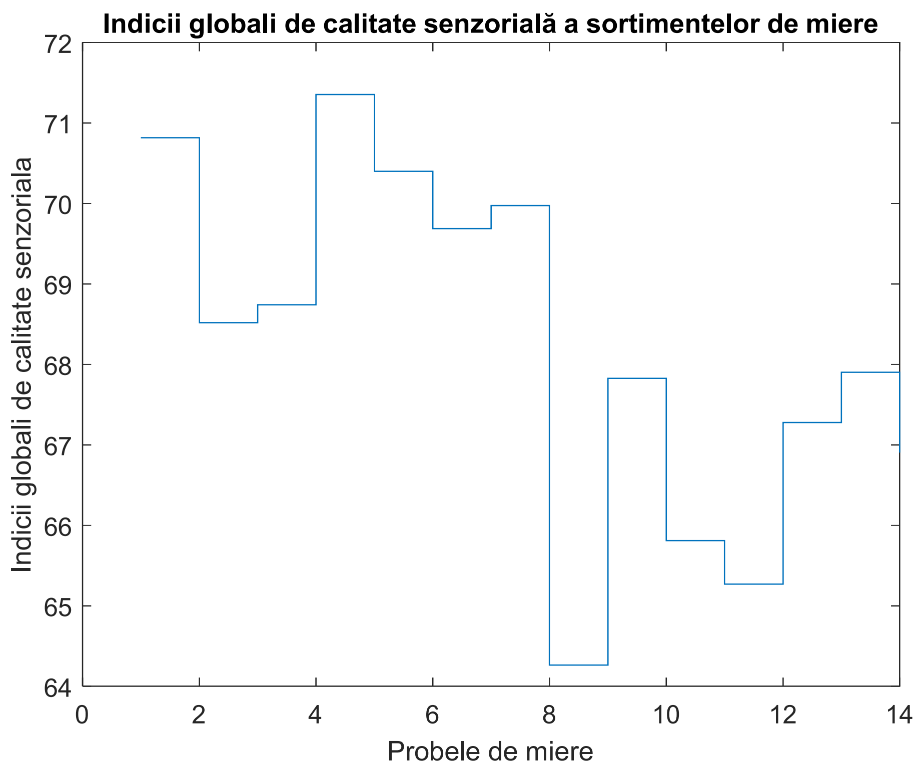

Figure 3. 7 Graphical representation of global sensory quality indices

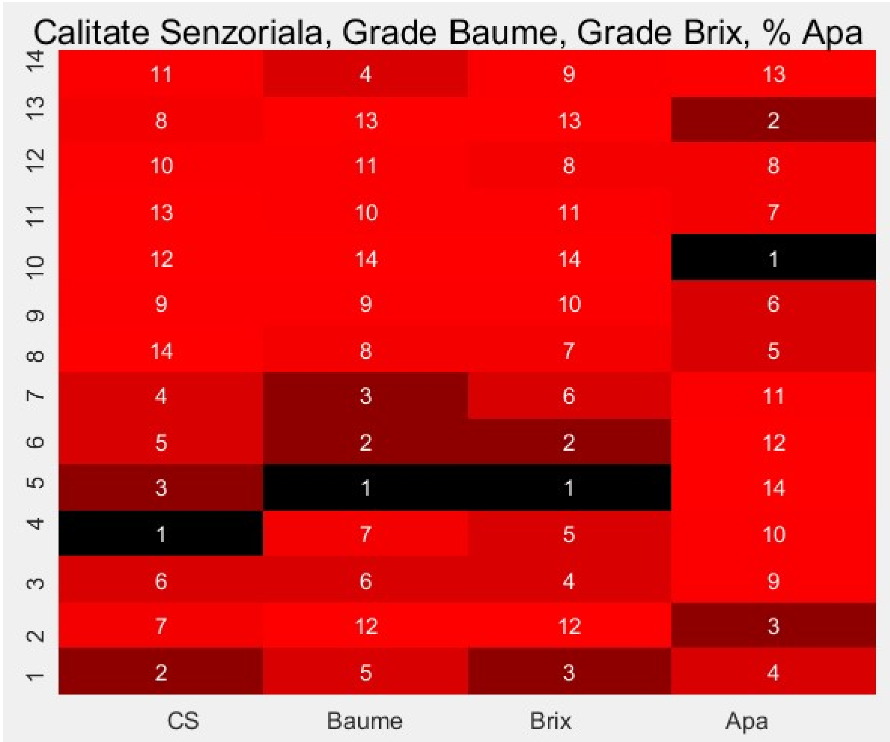

Figure 3. 8 HeatMap with sensory quality indices, Baume degrees, Brix degrees and water content for the analyzed honey varieties.

The fuzzy sensory analysis applied for the comparative analysis of American mint honey shows that this honey assortment is close in terms of global sensory qualities to acacia honey. These global sensory quality indices were calculated based on the perception of experts in relation to the attributes of sensory quality. The weight of the sensory quality indices of each quality attribute in the calculation of the global sensory quality indices of the honey assortments is also established based on the perception of the experts.

4. General conclusions, original contributions and perspectives

In the first chapter we analyzed the place of the role and importance of Romanian beekeeping at European level. We proudly found that Romanian beekeeping holds the first place in the EU from the perspective of total honey production. However, the level of production intensification is below the European average, twice lower than the most competitive production systems in Europe, which are found in Finland, Germany and the United Kingdom (Fig. 1.10.). This extraordinary economic potential that beekeeping has in Romania contrasts with the lack of competitiveness that manifests itself in the economy as a whole.

I propose through this doctoral thesis an integrated production model that offers advantages related to the intensification of beekeeping production and the increase of competitiveness within the agri-food system.

Intensive beekeeping integrated with aquaponic systems is a sustainable and extremely profitable economic activity.

With small investments for the acquisition of aquaponic microsystems, significant increases in honey and vegetable production are obtained, thus eliminating the impact of climate change.

The investments for the acquisition of an integrated aquaponic microsystem are 250 euros. They shall be recovered from the first year provided that the costs of transhumance are eliminated.

Reducing transhumance will lead farmers to adopt biodiversity conservation practices to increase wild pollinator populations.

In this doctoral thesis, we approached the integration of beekeeping with aquaponic systems to capitalize in the production processes of wastewater from recirculating aquaculture systems that have high concentrations of nitrites. Through nitrifying bacteria, wastewater is transformed into production factors for honey plants used in intensive beekeeping.

The main problem of recirculation systems in aquaculture is the production of waste rich in waste, the water to be treated and which causes environmental problems. For hydroponic systems, the main problem is the dependence on chemical fertilizers. By integrating these two technologies into aquaponics systems, the environmental problems that each of these technologies generates when operating separately are thus solved.

In this doctoral thesis we analyzed the possibility of acclimatization and also the production potential of the American mint Lophanthus Anisatus, in order to introduce it in aquaponic culture systems integrated with intensive beekeeping.

Intensive beekeeping integrated with aquaponic systems is a variant of high-tech beekeeping.

Aquaponia is a food production system that combines the production of hydroponic vegetables and aquaculture in a closed recycled system. This combination of multi-trophic integrated hydroponics and aquaculture production methods eliminates the problems associated with individual production methods.

The main objectives of integrated beekeeping in aquaponic systems are: the simultaneous integration of technical, economic, ecological, spatial and societal objectives in the development of the model of multifunctional aquaponic production platforms.

One of the most important aspects of aquaponics is the design of the system. The technical implementation of the correct type of aquoponic system will determine the success or failure of the business. Given this, the design phase of the aquaponic system is the first step towards a proper implementation process.

These intensive systems use water treatment plants to remove toxic products from organic waste produced by fish, as well as uneaten fish feed. Aquaponic systems integrated with intensive beekeeping offer the advantage of disposing of this organic waste by using it as a source of nutrients for honey plants in these systems. This integration solves the environmental problems represented by aquaculture wastewater, reduces total water consumption and also obtains nutrients that are used by honey plants. This synergy of the system represented by the integration generates an increase of the economic value that is obtained in each branch of production.

The aquaculture recirculation system aims to maintain good water quality. To do this, the water must be mechanically and biologically filtered to remove solids, ammonia and CO_2. Dissolved oxygen level, pH and temperature are also important parameters that must be at safe levels at all times.

Socio-economic impact assessment offers the opportunity to analyze the determinants of public attitude towards the use of multifunctional aquaponics. Compared to other industries in agriculture, beekeeping integrated in aquaponic systems is an ecological technology that does not use additional energy input in the integrated production system and also recycles wastewater from aquaculture through mechanical, biological filters and plant roots. The equipment needed for the integration of high-tech intensive beekeeping with aquaponics can be made by farmers locally and does not require sophisticated equipment, thus having the advantage of implementation in absolutely all regions. The only limiting factor is the lack of access to this diverse and complex knowledge that allows the profitable use of all these integrated technologies and which essentially does not refer to expensive equipment.

Compared to most other agricultural activities, intensive beekeeping integrated with aquaponic systems is a model of high-tech beekeeping. The equipment needed to make this high-tech beekeeping model can also be assembled locally by most beekeepers. The factor limiting the development of this technology is the lack of knowledge that the beekeeper must have in order to profitably use relatively complicated equipment from the perspective of process control that maintains the optimal conditions of aquatic, atmospheric and biological environment.

The model of intensive beekeeping integrated within an aquaponic system is a sustainable economic activity that fits very well with the concept of small-scale ecological agricultural development. It is an activity that makes intensive use of existing local resources and can be easily implemented in larger agricultural or aquaculture projects. Bees not only help pollinate crops used in such projects, but use otherwise unused resources: nutrients from wastewater from aquaculture, nectar and pollen.

As integrated bee colony management already exists in most regions of the world, the aim of this doctoral thesis is to develop a more efficient sustainable model. Thus, intensive beekeeping integrated into aquaponic systems is based on the introduction of new sustainable and more efficient methods in terms of exploitation and exploitation of resources at the ecosystem level.

All inputs of production factors necessary for the implementation of such an intensive beekeeping model integrated with aquaponic systems can be made locally, and do not generate any pressure on existing resources. This integration capitalizes on the waste that intensive aquaculture generates, thus providing nutrient resources for honey plants intended for intensive beekeeping. Thus, this sustainable model of intensive beekeeping can create consistent income for beekeepers for a longer duration of the production cycle by diversifying the activity in the field of aquaculture and vegetable growing.

Such a small intensive beekeeping project can be profitable from the beginning. After the initial period, as a result of the learning effect, the expertise will be gained, and it will be very easy for a beekeeper to increase the number of hives and the degree of intensification of production. By means of such a model, the dependence on the floral resources of external honey plants, deficient in the autumn periods, is reduced. During the winter, when the bees go into hibernation, beekeepers can obtain permanent income by capitalizing on vegetable crops grown in the aquaponic system and also fish production at competitive prices.

The bees that feed on the existing nectar and pollen resources in the area, suffer from their lack in the hot summer periods and in the late autumn periods. Such a model of intensive beekeeping integrated into aquaponic systems thus offers the advantage of consistent nectar and pollen resources that honey plants in aquaponic systems can provide to bees during periods when they are deficient in the external environment, while eliminating transport costs that are much higher in these periods.

Aeroponic modules for growing honey plants have been populated with seedlings grown outside this integrated system. Honey plants such as American mint (Lophanthus Anisatus) have low nutritional requirements and are thus well adapted to aeroponic systems integrated with recirculating aquaculture systems.

The support medium for honey plant growth in aeroponic modules is represented by a bed filled with lightly expanded clay aggregate (LECA) which ensures a strong growth of the roots through good ventilation for several vigorous plants. In practice, gravel, zeolite or expanded shale are also used as growth support. In the designed experiment will be compared all these growth environments, as well as continuous and discontinuous aeration flows.

The aeroponic module for growing honey plants has a constant spray regime with continuous flow.

The design of an aeroponic system consists of a plastic parallelepiped enclosure covered with a cover in which the growth medium of expanded clay or volcanic rock is fixed, plastic pipes through which water reaches the growth units and the pump from the filtration unit. which ensures the aeration of the water at the base of the growing environment.

The maintenance of an aeroponic system is not difficult because the solid organic matter is filtered by a mechanical filter and a biological filter, and the growth environment does not have direct contact with the effluent but only with the atmosphere generated in the aeroponic growth module. The roots of honey plants grow in the oxygenated atmosphere that is created in the aeroponic growth module.

An integrated aeroponic system with intensive beekeeping offers the opportunity to increase beekeepers' incomes, diversify production and reduce risks.

The integration of aeroponic systems with recirculating systems allows to obtain a production of fish as well as honey plants that are capitalized in intensive beekeeping, thus offering beekeepers an economically viable and sustainable production model from the perspective of environmental impact.

By integrating intensive beekeeping with an aeroponic system and a recirculating aquaculture system, the profitability of economic activity increases due to the fact that new inputs are used in the production process that do not generate additional costs. Another important aspect that determines the increase of efficiency is represented by the intensification of production and the reduction of production losses in all these branches of production integrated at the level of this sustainable production model. Diversification as an economic strategy has as its main advantage the reduction of risks. The risk is also reduced due to the fact that the final products obtained at the end of this integrated production cycle are non-perishable products with high added value. Aeroponics is starting to be an increasingly profitable economic activity, as a result of the benefits of reducing costs and increasing production efficiency throughout the production cycle. The level of risk of economic activity in the case of aeroponics integrated with intensive beekeeping depends on a variety of factors such as: system design, feed, pathogen control.

Nectar production is thus a function of the species, the positioning of the flower on the plant, the duration of flowering, the age of the plant, genetic factors. The size or texture of pollen grains lead to different collection strategies by bees. Climatic factors such as precipitation, temperature, sun, wind influence the production of nectar and pollen, as well as their harvest by pollinators. For cultivated species, the sowing period influences the period with floral reasons and, therefore, the availability of the resource for insect pollination. Some varieties or crops are likely to have different attractiveness, nectar and pollen supply characteristics than the type species. Much scientific data remains to be accumulated in this area. Honey flora is estimated at over a thousand species. This list can be reduced to 200 plants with a significant productivity index as a tool to help choose the species to be planted in order to intensify beekeeping. This classification was made according to several criteria, such as: plant type, flowering period, but also their availability in conventional distribution channels and among horticulturists (Annex 1). Annex 1 was developed on the basis of an assessment of the nectariferous and pollen characteristics of each species, based on bibliographic resources and expert advice. The tool used to evaluate the opinions of beekeepers in relation to the productive potential. This classification was made according to several criteria, such as: plant type, flowering period, but also their availability in conventional distribution channels and among horticulturists (Annex 1). Annex 1 was drawn up on the basis of an assessment of the nectariferous and pollen characteristics of each species, based on bibliographic resources and expert advice. The tool used to evaluate the opinions of beekeepers in relation to the productive potential. This classification was made according to several criteria, such as: plant type, flowering period, but also their availability in conventional distribution channels and among horticulturists (Annex 1). Annex 1 was developed on the basis of an assessment of the nectariferous and pollen characteristics of each species, based on bibliographic resources and expert advice. The tool used to evaluate the opinions of beekeepers in relation to the productive potential. based on bibliographic resources and expert sayings. The tool used to evaluate the opinions of beekeepers in relation to the productive potential. based on bibliographic resources and expert sayings. The tool used to evaluate the opinions of beekeepers in relation to the productive potential.

This survey was conducted in the South-East Region, between October 2019 and March 2020 on a sample of 50 beekeepers from the Association of Beekeepers (ACA). This sample was considered representative for estimating the productive potential using linguistic terms (small, medium, large).

This classification of productive potential (Annex 1) is of interest for meeting the pollination needs of insects during periods of food insecurity or high food needs. Not all species that may be of interest were included in this analysis. Thus, those honey plants related to the production of propolis are missing, due to the low availability of quantification methods and those related to the production of honey kernels. For each species listed, a confidence index was calculated on the estimation of nectar and / or pollen production from the number of bibliographic sources and expert feedback. This list partly responds to the actions developed as part of the sustainable beekeeping development plan (Annex 1). Designed as an evolving tool for users,

Starting from this integration of 3 productive systems, the objective of the research is to make an analysis of the global efficiency of this production model. Before starting the experiment, the honey plants of the species Lophanthus Anisatus were acclimatized to the specific local climate and soil conditions in Galati County for two years. With the seeds obtained from these plants, seedlings were grown in mini greenhouses. Also, the biological activation of the LECA culture substrate was performed in a recirculating mini-aquaculture system. Experimental design of 4 aeroponic modules was analyzed from the perspective of profitability.

In order for beekeeping to become a permanent source of income, its integration with aeroponic systems requires a projection of cash flow based on market conditions. According to market studies, mint is a honey plant with the highest economic value.

The variation of prices during the year for organic plants is quite small both internationally, remaining depending on the seasonality in the range of 17-22 euros per kg of dried leaves. It provides sustainability to integrated aeroponic systems that are implemented to grow Agastache foeniculum lophanthus honey plants for intensive beekeeping.

In aeroponic systems, mint can be harvested throughout the year, unlike open crops, in which the harvesting period is carried out during the flowering period, in June-September.

Up to 20 tons of fresh mint leaves can be obtained from 1 ha cultivated with mint in the open system. This green vegetable mass turns into 2-3 tons of dried mint. Planting a ha of open-pit mint amounts to planting material costs and planting and maintaining the crop for 5,000 to 6,000 euros. One kg of dried mint leaves on the local market sells for 30 lei, so an average profit of 10,000 euros per year can be obtained per hectare. Proper storage and drying in ventilated and dark spaces determines the quality and selling price.

At the same time, this plant has a special beekeeping importance, in North America being considered one of the most important plants for pollinators being visited by wild bees, honey bees, butterflies, bumblebees and other pollinators. It is estimated that half a hectare cultivated with this honey plant can support over 100 bee families, and aniseed honey is highly valued by Americans.

An economically viable aeroponic model of intensive beekeeping could be an economic motivation that would arouse beekeepers' interest in this honey plant, given that 1 kg of such honey is sold on the US market for $ 100. Lophanthus anisatus has a high resistance to diseases and pests, the pH of the substrate is recommended to be 6 - 6.5. We found that Lophantus anisatus is resistant to low winter temperatures. The plant enters vegetation since winter on the background of global warming.

The mint market is characterized by high demand for dried flowers with hyssop and anise flavor. The essential oil can be obtained from this plant by steam distillation. Plants that are in the stage of bud formation are preferably used. Methyl chavicol, a major component of this volatile oil that is obtained by fractional distillation and has various uses in downstream manufacturing industries.

The integration of intensive beekeeping with an aeroponic system and a recirculating aquaculture system can bring additional income to beekeepers throughout the year amid diversification of activity.

Also, the location of the intensive beekeeping system integrated with the aeroponic system is a very important decision. A semi-open system offers both the advantage of limiting exposure to climatic elements and the benefits of direct exposure of honey plants to sunlight.The decision of the location of the aeroponic system analyzes the advantages and disadvantages of indoor or outdoor variants. An aeroponic system located inside, controls environmental factors more easily but involves higher costs. Outdoor location is the cheapest, but it induces risks related to environmental problems.

The proposed aeroponic model does not use chemical herbicides and pesticides to obtain organic honey plants for the production of mint leaves and organic honey. There is a special interest of beekeepers in the production of organic honey.

Recirculating aquaculture systems replace very small percentages of the volume of water used. This amount of water that is replaced daily is used in the aeroponic system. The aeroponic system must provide the environmental conditions necessary for the growth of honey plants.

The most important parameters include nitrogen concentration and pH. The aeroponic system removes solid residues with the help of a mechanical filter, oxidizes ammonia and nitrite nitrogen with the help of a biological filter, removes carbon dioxide and aerates or oxygenates the water in the culture module where we find the roots of honey plants. Intensive systems may require the removal of fine solids or some form of disinfection. Cold plasma treatments offer the opportunity to disinfect the atmosphere created in the aeroponic module as well as the ionization of nitrogen which is thus processed by nitrifying bacteria.

In the model of intensive beekeeping system used in this experiment, aeroponic modules for growing honey plants are integrated with recirculating aquaculture systems. In this system, the mechanical filter removes solid residues, and the biological filter oxidizes ammonia and nitrite. This removes carbon dioxide and oxygenates the water before returning it back to the aquarium.

We chose the Japanese ornamental carp koi, as the main supplier of nutrients in the aeroponic system, because it is a species with a high economic value, an adult specimen is valued at 600 euros each, the most appreciated specimens reaching 15000 euros, and at the same time it is a species more resistant to variations in environmental factors. The use of Japanese ornamental carp as a source of nutrients for plants ensures a production of quality organic mint that is permanently controlled from the perspective of the parameters of the growing environment. Any change in the quality parameters of the water first affects the color of the carp, which is a visual indicator that signals the problems that occurred before affecting the health of the fish or the quality of organic mint production.

Aeroponics, integrated with recirculating aquaculture systems, is a production model that uses aquaculture nutrients and water filtration technologies much more efficiently than conventional agricultural production systems. Aeroponic systems have 4 times lower water consumption compared to conventional agricultural systems.Residual nutrients from the recirculating aquaculture system are thus used as the main factors of production.

Japanese ornamental koi carps need fodder to ensure their nutritional balance and energy needs through proteins, carbohydrates, fats, vitamins and minerals. Most plants get their energy directly from the sun while fish get their energy from metabolic chemical reactions.In the wild, carnivorous fish eat food that is nearly 50 percent protein. These fish have a very efficient system for excreting residual nitrogen from proteins.

Nitrogen waste comes from the breakdown of proteins. In the growing stage, the Japanese ornamental koi carp needs 25-35% protein in the diet. These omnivorous fish have moderate protein requirements compared to carnivorous fish that need 45% protein in their diet during development.Fats are a form of energy storage in both plants and animals. Natural diets have a content of up to 50% fat. Fish oil is commonly found as a component of fish feed.

For the feeding of Japanese ornamental carp from the aeroponic system integrated with the recirculating aquaculture system, we used a specific feed recipe for koi carp seedlings, with a granulation of 1.5-2 mm. This recipe contains a high amount of protein of 47%, which helps the development and growth of Japanese ornamental carp.

Proteins in fish feed are metabolized to ammonia. Ammonia occurs in two forms: ionized NH_4^+ and non-ionized NH_3. This ionized form is harmless to fish. The proportion of these forms of ammonia is determined by the pH of the water. As the pH increases, so does the concentration of hydrogen ions, and the proportion of unionized ammonia.

In this doctoral thesis I studied the possibility of introducing American mentions into intensive beekeeping, Agastache foeniculum lophanthus, grown in aeroponic systems. Mint honey, obtained in this intensive beekeeping system, allows the extension of the honey plant by bees. Mint honey has a higher concentration of antioxidants, in the form of phenols, compared to other varieties of honey. We used this mint honey in combination with the American mint extract obtained by cold pressing, in order to obtain mint liqueur in a proportion of 1/10 with alcohol. The by-products obtained by cold pressing American mint leaves were used to obtain mint syrup and mint sweetness by boiling in combination with lemon honey, lemon and ginger.

As integrated bee colony management already exists in most regions of the world, the aim of this doctoral thesis is to develop a more efficient sustainable model. Thus, intensive beekeeping integrated into aquaponic systems is based on the introduction of new sustainable and more efficient methods in terms of exploitation and exploitation of resources at the ecosystem level. All inputs of production factors necessary for the implementation of such an intensive beekeeping model integrated with aquaponic systems can be made locally, and do not generate any pressure on existing resources. This integration capitalizes on the waste that intensive aquaculture generates, thus providing nutrient resources for honey plants intended for intensive beekeeping. So, this sustainable model of intensive beekeeping can create consistent incomes for beekeepers for a longer production cycle by diversifying the activity in the field of aquaculture and vegetable growing. Such a small intensive beekeeping project can be profitable from the beginning. After the initial period, as a result of the learning effect, the expertise will be gained, and it will be very easy for a beekeeper to increase the number of hives and the degree of intensification of production. By means of such a model, the dependence on the floral resources of external honey plants is reduced, deficient in the autumn periods. During the winter, when the bees go into hibernation, beekeepers can obtain permanent income by capitalizing on vegetable crops grown in the aquaponic system and at the same time of fish production at competitive prices. The bees that feed on the existing nectar and pollen resources in the area, suffer from their lack in the hot summer periods and in the late autumn periods. Such a model of intensive beekeeping integrated into aquaponic systems thus offers the advantage of consistent nectar and pollen resources that honey plants in aquaponic systems can provide to bees during periods when they are deficient in the external environment, while eliminating transport costs that are much higher in these periods. The bees that feed on the existing nectar and pollen resources in the area, suffer from their lack in the hot summer periods and in the late autumn periods. Such a model of intensive beekeeping integrated into aquaponic systems thus offers the advantage of consistent nectar and pollen resources that honey plants in aquaponic systems can provide to bees during periods when they are deficient in

the external environment, while eliminating transport costs that are much higher in these periods. The bees that feed on the existing nectar and pollen resources in the area, suffer from their lack in the hot summer periods and in the late autumn periods. Such a model of intensive beekeeping integrated into aquaponic systems thus offers the advantage of consistent nectar and pollen resources that honey plants in aquaponic systems can provide to bees during periods when they are deficient in the external environment, while eliminating transport costs that are much higher in these periods.Aeroponic modules for growing honey plants have been populated with seedlings grown outside this integrated system. Honey plants such as American mint (Lophanthus Anisatus) have low nutritional requirements and are thus well adapted to aeroponic systems integrated with recirculating aquaculture systems.

American mint honey induces a menthol aroma because mint is rich in volatile oils, being considered a tonic product for the nervous system and a strong stimulant for the immune system through the action it has on the digestive system.

American mint honey has exceptional qualities being comparable to royal jelly or manuka honey, in terms of quality and purity. Unlike honey obtained from arboreal flowers, it, like polyfloral honey and honey obtained from the flowers of annual plants, has heavy metals in its composition (according to determinations with specific tests). In the usual honey from arboreal flowers or perennial plants near urban areas or roads we have identified high concentrations of heavy metals, due to air pollution in these areas.

The antibacterial properties of American mint have been exploited through products such as mint jam or mint liqueur.

Although mint honey has these precious qualities, it also has contraindications for people with obesity, diabetes, pancreatic insufficiency or those with allergic disorders.

This variety of honey has a greenish color that crystallizes into fine grains. According to the sensory analysis performed on the samples of American mint honey, it is found that it meets all the quality standards provided in the standard.

For the fuzzy sensory analysis of the honey samples we used membership functions with triangular distribution. Thus, the linguistic terms of perception with which experts appreciate the sensory characteristics of honey varieties are converted into so-called triplets belonging to three of the values of the scale.

The triangular belonging functions were used in this model to assess the degree of belonging to three of the linguistic terms, with different weights.

For the development of the fuzzy sensory analysis model of honey, we used Matlab R2020b which offers through its toolkit, the Fuzzy Logic Designer application with which we can model sensory perceptions in relation to the main quality characteristics of mint honey in relation with the other varieties of honey.

The sensory quality index of each honey assortment is obtained by converting qualitative assessments through linguistic terms into a set of 3 numerical values on a sensory scale of assessment of results with 5 linguistic values: unsatisfactory, satisfactory, average, good, excellent .

This set of 3 numerical values describes the function of triangular belonging to the five linguistic values. Each of the quality attributes in the sensory analysis has a relative weight in the total quality index. This relative weight is established on the basis of the assessments of a set of 20 consumers who provide assessments on the sensory quality of bee honey, as well as on the basis of physico-chemical determinations performed to highlight the quality of honey according to European and national standards. The relative weight that each sensory quality attribute has in the calculation of the global sensory quality index is established with the help of qualitative assessments, based on linguistic terms, using a fuzzy sensory scale.

The fuzzy sensory analysis applied for the comparative analysis of American mint honey shows that this variety of honey is close in terms of global sensory qualities, to acacia honey. These global sensory quality indices were calculated based on the perception of experts in relation to the attributes of sensory quality. The weight of the sensory quality indices of each quality attribute in the calculation of the global sensory quality indices of the honey assortments is also established based on the perception of the experts.

List of published and presented works

ISI indexed works as first author:

1. Constanta Laura AUGUSTIN (ZUGRAVU), Dr. Maria Magdalena TUREK RAHOVEANU, Dr. Daniela Ecaterina ZECA and Dr. Gheorghe Adrian ZUGRAVU, "Entrepreneurial Management in Intensive Beekeeping" to the International Business Information Management Conference (32nd IBIMA) Seville, Spain 15-16 November, 2018 has been accepted for presentation at the conference. The paper will be included in the conference proceedings (ISBN: 978- 0-9998551-1-9) as a full paper.https: //ibima.org/accepted-paper/sustainability-management-of-natural-areas-preserving-biodiversity/

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2. Constanta Laura AUGUSTIN (ZUGRAVU), Dr. Ciprian Petrisor PLENOVICI, Dr. Camelia FASOLA (LUNGEANU), Dr. Maria Magdalena TUREK RAHOVEANU and Dr. Gheorghe Adrian ZUGRAVU, Economic Feasibility Analysis in Aquaponicsto the International Business Information Management Conference (33rd IBIMA) Granada, Spain 10-11 April, 2019 has been accepted for presentation at the conference. The paper will be included in the conference proceedings (ISBN: 978-0-9998551-2-6) as a full paper;

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5. Constanta Laura AUGUSTIN (ZUGRAVU), Dr. Maria Magdalena TUREK RAHOVEANU, Dr. Ludmila MOGILDEA, Dr. Ciprian PLENOVICI and Dr. Gheorghe Adrian ZUGRAVU, Support Measures in the Beekeeping Sector, 37th IBIMA International Conference, Granada, Spain has been accepted for publication and presentation at the conference. The paper will be included in the conference proceedings (ISBN: 978-0-9998551-6-4);

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2. Constanta Laura Augustin (Zugravu), Cristian Muntenita, Ciprian Petrisor Plenovici, Gheorghe Adrian Zugravu, Environmental risk assessment of intensive beekeeping integrated with aquaponic system, Corresponding Author: Gheorghe Adrian Zugravu, "Dunărea de Jos" University of Galaţi, Galati, Romania, zugravuadrian@yahoo.com, Journal of Engineering and Science Research4 (2): 01-04,2020e-ISSN: 2289-7127 © RMPPublications, 2020DOI: 10.26666 / rmp.jesr.2020.2.1;

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