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CREATING A CLIMATE CAMERA FOR GROWING MICROGREENS: DESIGN, PARAMETERS AND POSSIBILITIES FOR APPLICATION

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Abstract

Microgreens are a new category of specialized vegetable crops that are included to the concept of fresh functional foods. The increased interest in this type of products has focused producers on the search for technological ways to produce them. One way to provide a practical application based decision is through the use of a climate camera. The creation of a climate camera with precise control of the growth and development conditions of microgreens is a key element of their production technology. This publication discusses the parameters necessary for optimal growth of microgreens. It describes the basic principles for the design of a climate camera for their cultivation. As a result of the review, it presents practical guidelines for successful design and application. The main conclusion is, the design of a climate chamber for microgreens is based on the correct choice of materials and creating the opportunity to control the main growth factors - temperature, humidity and light.

Key words*: microgreens, growth, climate control, smart box design.*

INTRODUCTION

Microgreens, or micro-plants, represent a rapidly developing field in agricultural and biological sciences. These plants, grown at an early stage of development, are used for various purposes – from scientific research to commercial production. Creating a climate chamber with precise control of conditions is essential for optimizing their growth. The chambers must provide a stable and controlled environment to maintain consistent growth and development of the microgreens. Growing micro-plants in a climate chamber is an innovation that is entering Bulgaria with great potential for development in the field of sustainable agriculture.

Microgreens are young plants grown in the early growth phase (usually 7-21 days) that are rich in nutrients, vitamins, minerals, and antioxidants. Studies show that they can contain significantly higher levels of nutrients compared to fully developed plants (Xiao Z. et al., 2012). Thanks to their health benefits and appealing appearance, they are widely used in culinary arts, functional nutrition, and dietetics. In Bulgaria, although interest in microgreens is growing, this is still a relatively new direction in the agricultural industry. The use of climate chambers for their cultivation allows precise control of conditions such as temperature, humidity, and lighting, which significantly accelerates growth and ensures a higher yield per area. With advances in agronomy and technology, climate chambers are becoming increasingly popular and provide new opportunities for farmers in Bulgaria to take advantage of the rapidly growing market for microgreens.

However, traditional methods of cultivation in greenhouses or indoors are often limited by factors such as seasonality, climate change, and high energy costs(Chiruta et al., 2024; Hoza et al., 2024; Iovita et al., 2024).

Creating a climate chamber that can provide perfectly controlled conditions for growing microgreens is of utmost importance for modern urban agriculture and vertical farming. Climate chambers offer a controlled environment in which key parameters such as temperature, humidity, light, and carbon dioxide (CO_2) concentration can be adjusted. These conditions allow optimization of the growth and quality of microgreens, such as regulating the light spectrum and intensity, which affects photosynthetic activity and the accumulation of bioactive compounds (Kyriacou M. C. et al., 2016) and (Samuolienė et al., 2013). Maintaining optimal levels of CO_2 is also essential for stimulating plant growth and development (Stutte G. W., 2006). Such a chamber would allow year-round production, minimizing losses and optimizing the quality of production.

The aim of the present study is to design and investigate a climate chamber for growing microgreens. This chamber will be developed with a focus on the following parameters:

1. Temperature: Precise control for optimal growth.
2. Humidity: Precise control for optimal growth.
3. Light: Regulation of the spectrum and intensity of lighting.

In addition, the article will discuss the possibilities for the application of the climate chamber in urban farming and the industrial production of microgreens.

MATERIALS AND METHODS

The construction of a climate chamber for growing plants requires careful planning and understanding of several key elements that provide the right conditions for growth. The main steps are the selection of size and materials for the construction of the chamber.

The size of the climate chamber depends on its intended use – whether it will be used for scientific experiments, industrial production, or personal needs. The main factors that determine the dimensions are the number of plants and the type of crops that will be grown in it. The chamber should have enough space for free growth of the crops. For example, for small experimental plants, it may have a volume of 0.5–1 m^3, while for industrial production it can reach several cubic meters. In our case, we are creating a chamber with internal dimensions (Figure 1) of 0.7 x 0.5 x 0.5 m with a volume of 0.175 m^3 intended for experimental and personal needs. The main goal for choosing this size is the mobility and the need to be easily portable with the possibility of installation on terraces and in small rooms.

Figure 1. Chamber with internal dimensions of 0.7 x 0.5 x 0.5 m with a volume of 0.175 m^3

The choice of materials is essential for maintaining optimal microclimate and efficiency of the chamber. Studies have shown that the most commonly used materials are:

- Polycarbonate panels – Lightweight, impact-resistant, and with good thermal insulation. They allow some light transmission.
- Aluminum or steel frame – Provides strength and stability to the structure.
- Chipboard or plywood with thermal insulation – A good option for budget chambers with a fixed location.
- Polyurethane foam – Provides additional thermal insulation.

Extruded polystyrene foam (XPS) (Figure 2), or its common name "Fibron", was used for insulation.

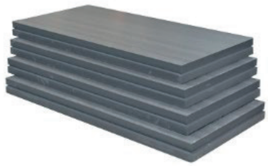

Figure 2. Extruded polystyrene foam (XPS)

The material is suitable for the production of floor, roof, and wall insulation. XPS offers very good thermal insulation with a thermal conductivity coefficient (λ) of about 0.029-0.035 W/mK. This makes it effective in preventing heat loss. Its density varies between 25 and 45 kg/m^3, depending on the manufacturer and intended use. Compressive strength under pressure at 10% deformation (20-40 kPa) depending on the type, but can reach 300 kPa for specific applications. Covered with a closed-cell structure, XPS is resistant to moisture and does not absorb water, making it vapor-tight and ideal for applications where moisture control is important, and with water absorption of less than 0.5% it is waterproof. Due to the chemical composition of the material, XPS is not subject to rot or mold growth. The box is lined on the outside with fiberboard and edged with PVC profiles for greater structural strength. Fiberboard is a composite material composed of wood fibers (Figure 3) bonded with adhesives, which is widely used in construction, furniture manufacturing, and interior design. Its density is usually between 600 and 800 kg/m^3. It is available in various surface treatments, including lamination, foil, melamine coating, or natural wood. It provides good thermal and sound insulation, making it suitable for lining the climate chamber.

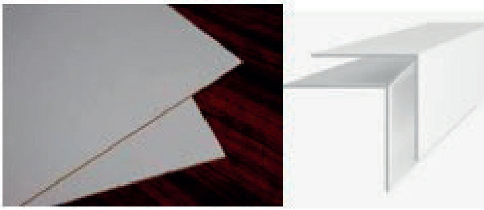

Figure 3. Fiberboard - composite material composed of wood fibers

For internal coating, the most commonly used materials are:

- Reflective film (Mylar) – Increases lighting efficiency by reflecting light back to the plants.
- PVC or aluminum foil – Easy to clean and moisture resistant.

Our choice is mirror window film. The mirrored part (Figure 4) is oriented towards the plants in order to reflect the emitted light towards the cultivated crops.

Figure 4. Mirror window film - the mirrored part

The main climatic factors that need to be managed include temperature, humidity, lighting, ventilation, and carbon dioxide (CO_2) concentration. Adjusting these parameters is key to creating optimal conditions for growing plants in laboratory and industrial settings.

Temperature Control

Temperature affects photosynthesis, respiration, and other physiological processes of plants. It is usually maintained in the range of 18-30°C.

Heating: Heating elements provide the necessary temperature, especially during the winter season (Liu et al., 2000). To ensure effective temperature control in the climate chamber, a system consisting of an electric heater and a fan that draws air from the external environment is often used. This configuration is assembled in a metal cylinder and allows maintaining optimal temperature conditions for plant growth by evenly distributing heat. At the end of the module, a V-shaped valve is mounted to prevent heat loss from the chamber to the environment. An electric heater with a supply voltage of 12V and a power of 110W (Figure 5) was used.

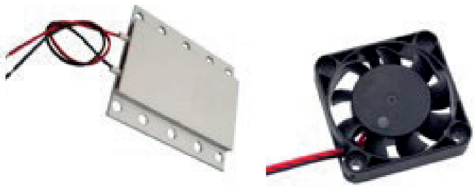

Figure 5. Electric heater with a supply voltage of 12V and a power of 110W

The fan is a 9CFM FD05015S, SPIRE, 4800RPM, 50x50x15mm, 12VDC with a flow rate of 15 m^3/h.

The configuration is mounted on the upper side edge of the chamber. The temperature is regulated by a programmable thermostat XH-W3002 designed for automatic switching on and off of the load at specific temperatures, equipped with a temperature sensor, model W3002 Digital LED Temperature Controller 12V/10A (Figure 6).

- Regulation range: -55 to +120°C.
- Temperature regulation accuracy: 0.1°C.
- Temperature measurement accuracy: 0.2°C.

Figure 6. Temperature sensor, model W3002 Digital LED Temperature Controller 12V/10A

Cooling: Cooling systems in climate chambers are essential for maintaining a stable tempera-ture, preventing overheating, and creating optimal conditions for plants. Depending on the scale of the chamber, the accuracy of control, and the budget, different types of cooling systems can be used. Air conditioning systems and fans regulate the temperature in warm conditions (Katagiri et al., 2015). The most commonly used temperature control systems are:

- Air cooling (fans and air exchange), fans. This is the simplest and most economical system, which is used to reduce the temperature by circulating air.
- Cooling with a compressor air conditioner - climate chambers with a built-in refrigeration compressor operate on the same principle as ordinary air conditioners - by circulating a refrigerant (freon).

Based on the conducted study, according to the volume and temperature requirements in the presented chamber, a system including Peltier elements with integrated water cooling of the hot part was manufactured and installed for the cooling system. Peltier modules (Figure 7) (thermoelectric coolers) generate a significant amount of heat while they operate. If this heat is not dissipated effectively, their cooling capacity decreases. Water has a much higher thermal conductivity (0.6 W/m·K) compared to air (0.026 W/m·K), a specific heat capacity of 4.2 kJ/kg·K, which means it can absorb more heat per unit mass without heating up significantly. Water cooling uses a radiator with a fan and circulating liquid, which means that heat is distributed more efficiently than with air cooling. The fans that blow the cold part of the module also help to evenly distribute the temperature in the box.

Figure 7. Peltier modules

The temperature is regulated by a programmable thermostat XH-W3002 designed for automatic switching on and off of the load at specific temperatures, equipped with a temperature sensor, model W3002 Digital LED Temperature Controller 12 V/20 A. The total power of the module is 144 W.

Air intake fan. The fan provides air circulation in the chamber and brings in fresh air from the external environment. Axial or centrifugal fans with a power of 5 W to 50 W are used, depending on the volume of the chamber. In our case, a fan model Sunon (Figure 8) EF92251S3 12VDC, 92 x 92 x 25 mm, 1.32 W, sleeve, 87.04 m^3/h was used.

Figure 8. Fan model Sunon EF92251S3 12VDC

To ensure optimal air circulation in the climate chamber, the fan is controlled by a time relay. This system allows periodic switching on and off of the fan, thus maintaining a uniform distribution of temperature, humidity, and CO_2 in the chamber.

Lighting and Photoperiod: Plants need adequate light for photosynthesis, and the spectrum and intensity of lighting must be tailored to their needs. The types of artificial light sources are:

- **LED lighting**: Allows adjustment of the spectrum to stimulate growth and flowering (Poorter et al., 2016).
- **Fluorescent lamps**: Suitable for laboratory conditions, but with less energy efficiency.
- **Sodium lamps**: Often used in greenhouse conditions.

For the purpose of the study, the most affordable waterproof LED strip with blue and red light was chosen. The distribution of diodes is 5:1 red to blue.

- LED type: SMD 5050
- Number of LEDs: 60 LED/m
- LED wavelength: Red: 660 nm; Blue: 450 nm
- Voltage: DC 12 V
- Power: 8 W/m, 36 W/5 m

A module (Figure 9) was made consisting of 9.5 m of the above-mentioned strip, attached to an aluminum plate with dimensions... with a mounted aluminum radiator to dissipate the heat generated by the LED strip. The amount of light delivered to the plants is 1010 lx. Lux (lx) is a unit of measurement for illuminance, which describes the amount of light falling on a surface. One lux is equal to one lumen per square meter (l m/m²).

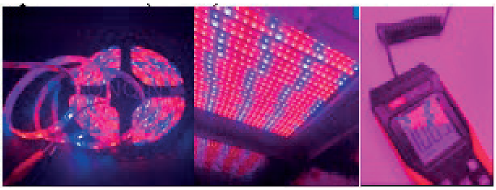

Figure 9. Waterproof LED strip with blue and red light

Plants have two main pigments that absorb light for photosynthesis:

- **Chlorophyll A**: Absorbs blue light best around 430 nm and red light around 662 nm.
- **Chlorophyll B**: Absorbs blue light around 453 nm and red light around 642 nm.
- **Blue light (450-470 nm)**: Stimulates vegetative growth - enhances the formation of leaves and stems, improves branching and makes plants more compact. It helps in the development of the root system.
- **Red light (620-680 nm)**: Accelerates flowering and fruiting, supports leaf expansion, increases the production of flowers and fruits.

The photoperiod is 12/12 h, controlled by a time relay T2310 (Figure 10) DC 12V which allows timer modes of 000-999 sec., 000-999 min., 000-999 hours. Times can be combined (example: working in seconds and off position in hours).

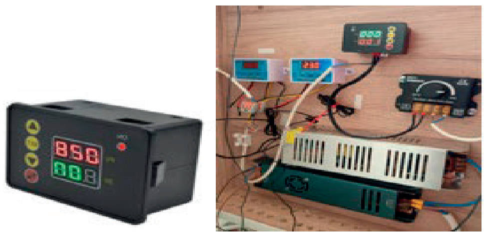

Figure 10. 12 Volt Time relay – T2310

RESULTS AND DISCUSSIONS

The climate chamber is designed to provide stable conditions for growing microgreens. The temperature conditions in the chamber are maintained with stable heating via a module with a fan and heating element, which provides minimal fluctuations (around 0.4°C) around the desired temperature of 23.5°C. The heating works stably even at external temperatures in February from -5°C to 12°C during the day and internal room temperatures from 2°C to 12°C. The hysteresis of the thermostat (switching on at 23.1°C and switching off at 23.5°C) ensures minimal variations. Cooling with Peltier elements is not activated under these conditions, as the external temperatures are not low enough to cause the need for cooling in the chamber.

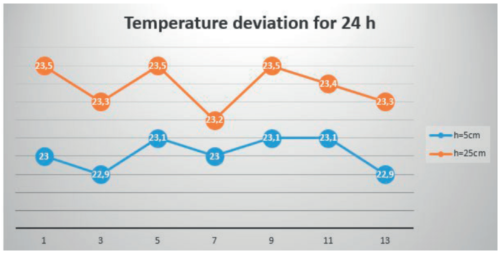

Figure 11. Fluctuations in temperature over time at different heights

When measuring the temperature at different levels in the chamber, it was found that at the bottom it is 23°C and at a height of 25 cm it is 23.5°C, where the are located the top of microgreens (Figure 11). This indicates small fluctuations in temperature at different heights, which are due to heat circulation and air distribution. The air circulation in the chamber is provided by a 12-volt fan with a flow rate of 42 cubic meters per hour, which ensures even distribution of temperature and prevents the accumulation of hot zones.

The humidity in the chamber was monitored with a hygrometer, with normal humidity being around 26%. After watering, the humidity increases to 32%, but does not remain at higher levels, which is typical for manual watering.

Lighting in the chamber is provided by LED strips with a power of 8W per meter, located at 9.5 meters in total. The distribution of strips with 5 red and 1 blue diode is optimized for maximum growth of microgreens. The illuminance reaches 1075 lux at a distance of 40 cm from the strips, which is suitable for plant growth. After the selected studies, selection trials were conducted with radish test plants while observing the temperature dynamics. The experimental conditions included different combinations of the height of the seed container from the bottom of the chamber and different light intensities. At a bottom height of 50 cm and a light intensity of 1010 lux, a 5:1 red to blue ratio, the plant reached a height of 12.5 cm on the 5th day after sowing. Changing the height to 38 cm and increasing the light to 1700 lux with the addition of white light 5:1:1, on the 5th day the plants were 7 cm. The specific difference in appearance is directly related to the vitality of the plants and the commercial appearance of the finished product (Figures 12 and 13).

Figure 12. Case 1: 12.5 cm plants under 1010 lux 50 cm height lights

Figure 13. Case 2: 7 cm plants under 1700 lux, 38 cm height lights

Our preliminary results agree with the findings of Gunjal et al. (2024).

Analysis of variance (ANOVA) was conducted to establish the relationship and strength of influence of light intensity on plant growth (Table 1).

Table 1. ANOVA statistical analysis

Source of Variation	SS	df	MS	F	P-value	F crit	strength of influence
Between Groups	6740186	1	6740186	205,4	0,00	4,4	92%
Within Groups	590772,4	18	32821				8%
Total	7330958	19					

A strong correlation between light intensity and plant height was found - 92%. This relationship is described by the following linear equation $y = -79.354x + 2008.8$ (Figure 14).

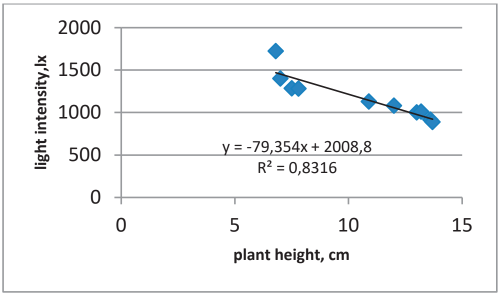

Figure 14. Correlation between light intensity and plant height

The high coefficient of determination (0.832) shows that at a light intensity of 1400 lux, the height of the plants will be 7-7.5 cm with a probability of 83%. It is statistically proven at a level of significance of 5%.

CONCLUSIONS

The present results demonstrate that the climate chamber provides stable conditions for growing microgreens at low external temperatures. The heating system maintains the desired temperature of 23.5°C with minimal fluctuations of 0.4°C, with cooling via Peltier elements not being activated under the current conditions.

Air circulation, provided by a 12V fan with a flow rate of 42 m³/h, contributes to the even distribution of temperature. Illumination of 1075 lux at 40 cm from the LED strips with an optimal ratio of red and blue diodes is suitable for the growth of microgreens.

Air humidity remains relatively low (26-32%), with a temporary increase observed after watering. This indicates a need for additional humidity management measures if the goal is to optimize growing conditions.

Based on these results, the climate chamber can successfully maintain the necessary parameters for growing microgreens. Future improvements could include automated watering, humidity control, and additional temperature measurements at different heights to further optimize the environment.

The main parameter of the climate camera for growing microgreens, which is important for the height of the plants, is the light intensity.

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