PREPARATION OF BIOMASS SEEDLING TRAYS USING LIGNIN BONDING PROPERTIES AND DESIGN OF HEATING COMPRESSION FORMING MOLD
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基于木质素粘结特性的生物质育苗盘制备及热压成型模具设计

Jin-yang LI[1)], Wei ZHANG[*2)], Chun-tao YU[2)], Li-qiang QI[2)] , Bo ZHANG[1)]
[1)]College of Information and Electrical Engineering, Heilongjiang Bayi Agricultural University, Daqing/P.R.China
[2)]College of Engineering, Heilongjiang Bayi Agricultural University, Daqing/P.R.China
Tel: +86-459-15246110999; E-mail: zhang66wei@126.com
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ABSTRACT
In the current agricultural production, widely used plastic seedling trays suffer from poor air permeability, poor water permeability, and slow degradation. Therefore, this study proposes the preparation of degradable seedling trays utilizing the bonding effect of lignin, and the design of a heating compression forming mold according to the size and forming requirements of the trays. Flexural strength of seedling trays and seedling experiments were conducted to verify the effectiveness of the preparation process and mold design. The experiment results showed that the heating function requirements of the mold can be achieved when the heating power of the electromagnetic induction heater was set to 3000 W, and the heating time of the frame was 60 s. The heating compression mold designed can ensure that the seedling trays were heated uniformly and have excellent mechanical properties during the forming process. Biomass seedling trays prepared using lignin bonding and specific raw material ratios performed well in terms of compressive strength, water resistance and degradability. During the seedling cycle, no rupture occurred in the seedling trays, and the growth of maize seedlings was good enough to meet the actual seedling needs. The results of the study provide new ideas and methods for the preparation of lignin bonding degradable biomass seedling trays, and the application of heating compression forming mold provides technical support for the efficient and large-scale production of seedling trays.

摘要
针对当前农业生产中广泛使用的塑料育苗盘存在透气性差、透水性不佳以及难以降解等问题，本研究提出了利用木质素粘结作用制备可降解育苗盘，根据育苗盘的尺寸和成型需求，设计加热压缩成型模具。为验证制备工艺和模具设计有效性，进行了育苗盘抗弯强度及育苗试验。试验结果表明，在电磁感应加热器的加热功率设置为 3000 W，料框加热时间为 60 s 时，可达到模具加热功能要求。本研究设计的加热压缩成型模具能够确保育苗盘在成型过程中受热均匀并具有优异力学性能。利用木质素粘结及特定原料配比制备的生物质育苗盘在抗压强度、耐水性和生物降解性等方面均表现出色。在育苗周期内，育苗盘未发生破裂现象，玉米苗长势良好，能够满足实际育苗需求。研究结果为木质素粘结型可降解生物质育苗盘的制备提供了新的思路和方法，加热压缩成型模具的应用为育苗盘高效、规模化生产提供了技术支持。

INTRODUCTION
Maize is an important food crop and feed crop with large production potential and high economic benefits, and has an important strategic position in guaranteeing food security. Transplanting can prolong the growing period and improve the quality of maize, and the use of transplanting methods can solve the problems of short frost-free period, large temperature difference and low maturity of maize in the process of planting maize, so as to achieve stable and high yields of maize planting. The role of seedling trays in crop seedling and crop growth period has become particularly important.

Nowadays, the most used seedling trays are made of plastic, but the air permeability and water permeability of plastic are not satisfactory, and also has the disadvantage of difficult to degrade and cause pollution to the environment. In recent years, experts around the world have devoted more attention to the research and development of seedling containers using biodegradable materials.

[1]*Jin-yang LI, Ph.D.; Wei ZHANG, Prof. Ph.D.; Chun-tao YU, Ph.D.; Li-qiang QI, Ph.D.; Bo ZHANG, Ph.D.*

Biodegradable materials are characterized by non-toxicity, biocompatibility, and biodegradability, and are able to break down over time in the natural environment, doing so more rapidly than traditional materials *(Chen et al., 2023)*. Seedling trays prepared from this material have good water permeability and air permeability. The degradation of seedling trays can increase the content of soil organic matter and soil fertility in the late stage *(Choudhary et al., 2023)*. At the same time, waste resources can be effectively utilized by finding degradable materials to replace the original production materials *(Guerrini et al., 2017)*.

Biomass materials are an important branch of biodegradable materials, mainly derived from agricultural crops and their processing residues and wastes, and can be used to prepare seedling trays *(Li et al., 2022)*. Recent studies have further advanced the processing of agricultural waste. *Cheng et al. (2025)* developed a twin-screw straw pulping machine, which provides efficient technical solutions for converting straw into moldable substrates, laying a foundation for the large-scale production of biomass seedling trays.

The development of compression forming for biomass materials has enabled the effective conversion of what might otherwise be bulky and misshapen agricultural waste into seedling containers with standard dimensions and excellent physical properties. When the material is compressed and molded, the void space between each particle will change due to pressure *(Komine et al., 2023)*. After filling the mold with the material in the experiment, the elastic deformation of the particles will result in the destruction of the physical structure due to the positional changes produced by the original particles to achieve full filling *(Clemmer et al., 2023)*.

Li et al. (2014) used oligosaccharides production waste as the main raw material to prepare degradable seedling trays with good mechanical strength and water absorption by hot pressing process. *Wan et al. (2020)* prepared lycopene biomass seedling trays using rice straw and cow dung. *Juanga-Labayen et al. (2021)* used textile wastes mixed with paper scraps to make biodegradable seedling trays, which met the commercial standards in terms of compressive strength, degradability and seed germination.

Biomass solids forming processes can be classified into wet compression, carbonization, and heating compression forming *(Jian et al., 2013; Wang et al., 2017)*. The characteristics of the three forming processes can be found in the literature *(Xie et al., 2020; Guo et al., 2023)*. The heating compression forming is currently the most widely used process for biomass compression forming. Existing biomass heating compression forming process is mainly for biomass fuel pellet forming, and its main forming relies on the internal fiber structure of the mechanical mosaic, so it has a low moisture content, and the adhesive effect of lignin will avoid the expansion of the particles after the forming of the phenomenon of flaccidity. Meanwhile, efforts to optimize forming parameters have been made. *Yaheliuk et al. (2025)* optimized the technological parameters for producing fuel rolls from crop stem biomass, which offers insights into improving the forming efficiency and stability of biomass materials in thermal compression processes, including seedling trays.

The strength of particles after compression includes adhesion, inter-particle attraction, collision force, surface tension, solid bridging force and capillary force *(Rumpf et al., 2023)*. Compared with biomass forming fuel pellets, the structure of the seedling trays is complex, low moisture content of the material heating compression forming method cannot meet the needs of its structural filling, the need for the material in the compression process with a certain degree of mobility, and to make the biomass material within the lignin to a greater extent to play its role in the adhesion. Relevant research on composite materials has shown that the mechanical properties of agricultural waste-based composites can be adjusted by regulating additive concentrations *(Farcaș-Flamaropol et al., 2024)*, which guides the design of biomass seedling tray formulations to meet strength requirements.

Therefore, the purpose of this paper is to design a new biomass seedling trays forming mold for maize seedling transplantation. It is necessary to meet the requirements of forming dimensions and forming conditions for the preparation of biomass seedling trays without the addition of adhesives. After the completion of the equipment, the testing of the equipment includes the use of the equipment to make seedling trays, the bending resistance test and seedling test of the seedling trays to ensure that the seedling trays made through the mold can be used in practice.

MATERIALS AND METHODS

Selection and treatment of materials for seedling trays preparation

The cow dung and rice straw are suitable for use as seedling trays because they have the advantages of a wide range of material sources, a simple preparation process, and do not pollute the soil. Therefore, in this paper, cow dung and rice straw were selected as the raw materials for the preparation of biomass seedling trays. Cow dung and rice straw are mainly composed of lignin, cellulose, and hemicellulose, which together form the structural skeleton that supports plant cells and structures.

Lignin is a complex structure that is insoluble in water in an acidic environment and cannot be hydrolyzed. It is a polymer aggregate with glass transition properties *(Luo et al., 2019)*. When the heating temperature increases to the critical point, the unique glass transition characteristics of lignin will produce good adhesion, which can be used as a binder to achieve bonding effect in biomass compression molding *(Wang et al., 2016)*.

The cow dung was obtained from Beingmei Industrialized Dairy Cattle Breeding Base, Anda City, Heilongjiang Province, China (46°27′3'' N, 125°22′50'' E). The rice straw was obtained from Wutong River Farm, Tangyuan County, Jiamusi City, Heilongjiang Province, China (47°12′56'' N, 130°49′15'' E). The concentrations of lignin, cellulose and hemicellulose in cow dung and rice straw used in the experiment are shown in Table 1.

Table 1

Concentrations of lignin, cellulose and hemicellulose in cow dung and rice straw

Ingredient	Cow dung	Rice straw
Lignin (%)	26.43 ± 0.46	14.72 ± 0.26
Cellulose (%)	17.67 ± 0.72	39.35 ± 0.31
Hemicellulose (%)	21.10 ± 1.41	36.08 ± 0.42

The natural drying method was used to treat the rice straw, and the drying treatment was finished when the moisture content of the straw detected by the moisture content detector (SFY, Guanya Electronic Science and Technology Co., Ltd., Shenzhen, China) reached less than 15%. The dried rice straw was placed in hammer mill (Filtra, FML2000, Spain) and filtered using a 5 mm round-hole sieve accompanying the machine, resulting in a final crushed stalk length of 5 mm±1 mm. Cow dung samples were taken and placed in a light-proof and ventilated environment for shade drying to reduce the moisture content, until the cow dung was in the form of lumps and the moisture content was 23%±1%. The dried cow dung and crushed rice straw were put into a mixer (Bingcheng, BH-12.5, Harbin, China), with a mixing speed of 20 r/min and a mixing time of 10 min, until the cow dung was in a loose state, at which time the looseness was 0.42 t/m^3. The mass ratio of the cow dung to the rice straw was 90% and the moisture content of the experimental prepared biomass material detected using the drying method was 21%±0.6%.

Dimensions of biomass seedling trays

Based on market research and maize seedling agronomic requirements, seedling tray dimensions were determined as follows: considering the tray bottom thickness and water - storage need during seeding, the height was set at 35 mm (with a 3.5 mm - thick tray, the effective depth is 31.5 mm to keep seedlings intact after transplantation). Referring to common market plastic tray sizes, the longitudinal dimension was 42 mm. Thus, each cell size is 35 × 42 × 31.5 mm.

Current automated rice transplanting equipment is well-developed. In designing maize seedling trays, the maximum lateral space (285 mm) of the most widely used rice transplanter's tray holder was adopted. Combined with the pre-determined single pot volume range and need for 6 pots per row, the final single tray length is 276.5 mm, giving an overall size of 276.5 × 42 × 35 mm. Specific parameters are shown in Fig.1.

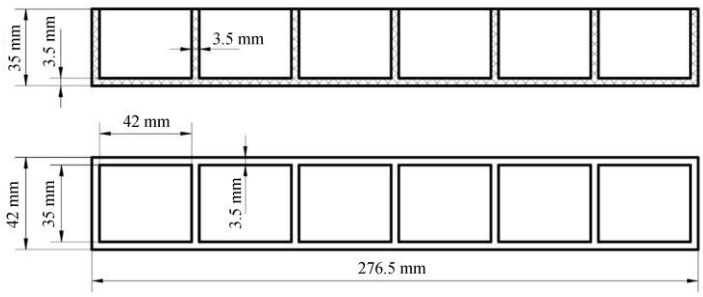
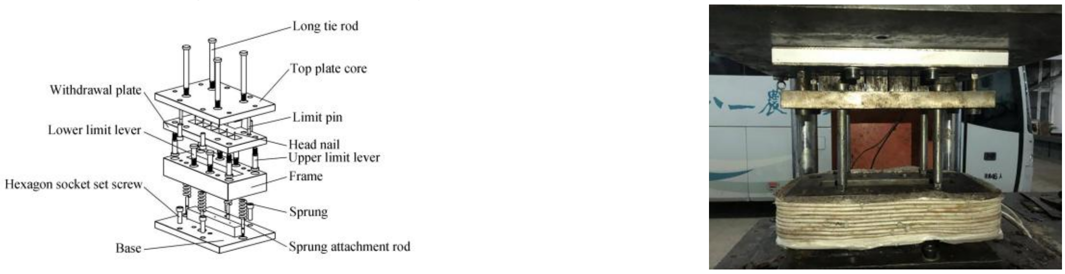


Fig. 1 - The parameter design of seedling tray

The mold design for biomass seedling trays

Biomass materials with cow dung and rice straw as the main raw materials are viscoelastic materials, and it is a large deformation process to compress them from a loose state into seedling trays with a certain shape and degree of compactness. Biomass material has the nature of a fluid, but its fluidity is poorer than bulk, worse than fluid, so it is not a fluid, also different from bulk. In view of its characteristics, it is a more feasible way to design the forming molds for biomass seedling trays by using a closed forming structure.

According to the function in the forming process, the basic composition of the mold was mainly divided into forming parts and structural parts. The forming parts included convex mold, concave mold, frame, withdrawal plate and base. They were in indirect contact with the synthetic material of the seedling tray and completed the main functions during the forming process. The structural parts included long tie rods, upper limit levers, lower limit levers, sprung assemblies and limit pins. They were not in direct contact with the material and played a role in mounting and positioning. The schematic diagram of the basic structure of the mold and the final design of the mold's physical effect are shown in Fig. 2.



（a）The basic structure of the mold （b）The final design of the mold's physical effect

Fig. 2 - The schematic diagram of the basic structure of the mold

The heating function design for mold

The existing forming molds for maize seedling trays have a compression forming process that is usually carried out at room temperature. However, during the process of biomass material being compressed, although the extrusion and friction between particles will lead to some increase in the temperature of the material, this temperature increase is far from the required temperature (170 ℃) for the accelerated softening of lignin *(Jiang et al., 2015)*. As a result, the lignin within the compressed biomass material cannot be liquefied and precipitated under the existing forming pressure. In order to enable the biomass material to reach the glass transition temperature of lignin after compression, further design and incorporation of heating function is required on top of the compression function of the existing mold. This enables the mold to warm up the internal material when compressing the biomass material, ensuring that the material reaches the required softening temperature and thus optimizing the forming effect.

The electromagnetic induction heating is a heating method that acts directly on the metal material. This method acts directly on the metal material without the need for a heat transfer medium, making it possible to achieve higher heating efficiency and energy utilization *(Li et al., 2024)*. Therefore, the electromagnetic induction heating was chosen as the heating method for mold warming in order to achieve a more efficient heating effect and energy utilization.

The operating frequency of electromagnetic induction heating has a close relationship with the position of the eddy current heating depth of the electromagnetic coil. Different operating frequencies lead to different heating depths, as shown in equation (1) for the calculation process of heating depth.

$$\delta = \frac{30}{\sqrt{f}} \tag{1}$$

where: f is the frequency, [kHz]; δ is the heating depth, [mm].

The heating simulation of the frame

In order to simulate the heating power of the electromagnetic induction heater and the temperature troughs and distribution of the inner wall of the frame after heating, and to provide a reference for the adjustment of the power range of the electromagnetic induction heater at a later stage, the heating simulation of the frame was carried out. The SolidWorks Simulation function module was used to simulate the heating process of the frame.

The model was drawn to the frame's actual dimensions (373 × 182 × 80 mm), with total transient time set to 60 s and time increment of 6 s. Ordinary carbon steel, consistent with the part's actual material properties, was defined for the frame.

For the temperature setting, the ambient temperature was set to 300 K (26.85 ℃). For the heat setting, the four sides of the inside of the frame were selected as contact surfaces to ensure that the heat could be transferred accurately. Based on the characteristics of air heat transfer, the heat dissipation on the inner surface was set to 0.2 W to ensure uniform heat distribution.

It should be noted that this value of 0.2 W was determined through multiple repeated experiments, where different heat dissipation values were continuously tested and the corresponding heat distribution effects were observed, ultimately being confirmed that 0.2W could achieve the desired uniform heat distribution.

In addition, in order to simulate the convection effect during the actual heating process, the convection option in the thermal load was selected and the convection coefficient was set to 25 W/(m^2·K) for the four faces on the outside of the mold. Similarly, this convection coefficient of 25 W/(m^2·K) was obtained through a series of repeated experiments. Numerous tests were conducted with various convection coefficient values, the simulation results were compared with the actual heating conditions, and after repeated verification and adjustment, it was determined that 25 W/(m^2·K) was the most suitable value to simulate the actual convection effect. The corresponding total ambient temperature for external heating was set according to the power of the induction heating unit. When the power was 2000 W, the ambient temperature was set to 430 K; when the power was 3000 W, the ambient temperature was adjusted to 600 K; and when the power reached 5000 W, the ambient temperature was set to 960 K.

Preparation of biomass seedling trays

For the preparation of compression formed maize biomass seedling trays at room temperature, 300 g of treated biomass material (90% mass ratio of cow dung to rice straw and 23% moisture content) was placed in the forming mold. The mold was compressed using electronic universal testing machine and pressure of 25 MPa was selected to ensure that the material was fully compressed and shaped in the mold.

In preparing compression formed maize biomass seedling trays under heated conditions, the induction coil of electromagnetic induction heater was tightly wound around the outer surface of the mold frame. By precisely adjusting the current output of the electromagnetic induction heater, the inner surface of the mold was heated to 240 ℃ and this temperature was kept constant. Other than that, the rest of the operation steps remained the same as the preparation process under room temperature conditions. After compression and holding for 20 s, waiting for the temperature of the mold to naturally drop to below 50 ℃ before carrying out the demolding operation. This procedure ensured the stable quality of the formed seedling trays, with regular dimensions, intact structures, and no obvious defects.

Flexural strength test of seedling trays

This study aimed to investigate the source of strength of biomass seedling trays and the role of lignin in the forming process through a comparative analysis of the changes in flexural strength between room-temperature compression forming and heating compression forming of the trays. The seedling trays were placed on the test platform of electronic universal testing machine (WDW-200EIII, Jinan Golden Age Testing and Measuring Machine Co., Ltd., Jinan, China), which complied with GB/T 16491-2008 standard. Fig. 3 shows the flexural strength test of seedling trays using electronic universal testing machine. The test was based on GB/T 1449-2005, using unconstrained support to destroy the seedling trays by three-point bending at a constant loading rate of 10 mm/min. The termination position at the closed loop control was set to 6 mm with a hold time of 10 s. The span and the position of the upper press head were adjusted to 0.5 mm, and the span used in this test was 210 mm.

Fig. 3 - The flexural strength test of seedling trays using electronic universal testing machine

Seedling experiments using seedling trays

The purpose of the seedling experiments was to verify the applicability and effectiveness of the seedling trays in practical use, and to determine whether they could withstand the pressure exerted by plant growth. In addition, the performance data of the seedling trays provided a basis for subsequent improvement and optimization.

The maize variety selected for this experiment was Demeria 3, a maize hybrid selected by KWS, Germany. Two to three days before sowing, the maize seeds were soaked in warm water at 28 to 30 ℃ for 12 hours, fished out and filtered dry of excess water. The treated maize seeds were evenly spread in culture trays with a layer of non-woven fabric fully saturated with water at the bottom of the trays. The seeds and trays were placed in a thermostat at 30℃ for 24 hours for germination. After germination was completed, 20 mm thick subsoil was placed in the holes of the seedling trays. One maize seed was inserted into each hole and filled with topsoil until it was level with the upper edge of the seedling trays. Water was poured into the trays until the soil was completely saturated. The ambient temperature of the trays was controlled at 25℃ ± 3℃ throughout the seedling process. Ventilation was carried out regularly on a daily basis and watering was carried out once in the morning from 8 to 9 am to ensure proper growth of the maize seeds.

RESULTS

Analysis of the heating location

According to the structural characteristics of the maize seedling trays, theoretically, heating from the inner wall and outer wall of the seedling tray hole can most effectively achieve the common heat inside and outside, so that the seedling tray as a whole reaches the glass transition temperature, and ensure the most uniform temperature distribution. The parts in contact with the maize seedling tray mainly include the top plate core, withdrawal plate, frame and base. Among them, the top plate core was in contact with the inner wall, the frame was in contact with the outer wall, and the base was in contact with the bottom of the seedling tray. Therefore, the heating efficiency of the maize seedling tray can be significantly improved by heating the top plate core and the frame specifically.

After the seedling tray has been compressed, direct internal heating is difficult to achieve because the top plate core is located inside the mold. If heating is attempted from the outer edges of the top plate core, there will be a large energy loss in the process of heat transfer to the top plate core, so this heating method is not ideal. Comparatively speaking, the inner wall of the formed frame and the outer wall of the seedling tray are in close proximity to each other, and the inner wall of the frame has the largest area of contact with the compressed biomass material, except for the top plate core. By heating the frame, the heat can be effectively and uniformly transferred to the maize seedling tray. Therefore, the electromagnetic induction coil was wound on the outer surface of the frame, and the electromagnetic induction principle was used to heat up the frame, so as to achieve the purpose of heating the internal biomass material.

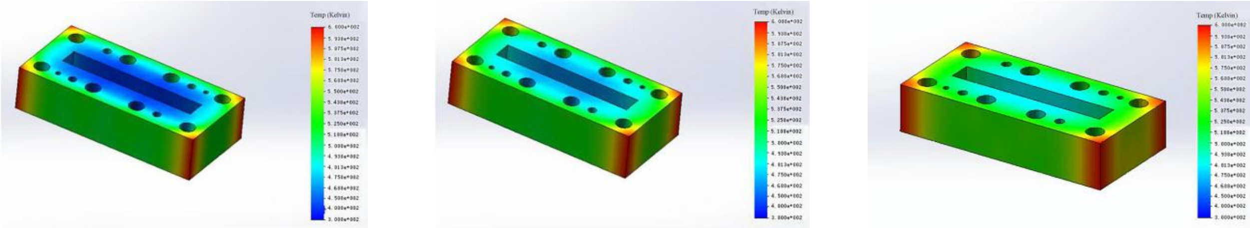
In order to penetrate the 5 mm thick glass insulation cotton outside the mold and form an effective vortex heating layer in the outer frame of the mold, an operating frequency of 20 kHz was selected according to the frequency adjustment range of the electromagnetic induction heater. The heating depth at this frequency can reach 6.7 mm, which fully meets the heating demand.

Results of the heating simulation of the frame

In the preliminary simulation, at a heating temperature of 430 K, it took up to 103 s to reach the target temperature of 170℃ to 270℃ at each point of the inner wall of the frame, which was obviously not satisfactory. In the simulation conditions of 960 K, although the heating speed of the frame significantly increased, only 24 s the highest temperature exceeded 270℃, but at the same time, the lowest point of the temperature failed to reach 170℃, the temperature difference between the inner wall of the frame was significant, and could not meet the requirements of the uniform heating of the material. In view of this, this paper adopted the heating temperature of 600 K to simulate the frame. After 30 steps of iterative solution, the heating process of the frame in 60 s was obtained. The heat distribution of the frame at 20 s, 40 s, and 60 s of heating was plotted, as shown in Fig. 4, to visualize the distribution at different heating stages.

From the Fig.4, it can be seen that within the first 20 s heating, the temperature had not yet penetrated deep into the frame, but was mainly concentrated in the outer corners. Due to the dense electromagnetic induction lines in these areas, the temperature rapidly rose to the peak heating temperature of 600 K. As the heating time progressed, by 40 s, the color inside the frame gradually shifted from dark blue to light blue, indicating that the temperature had steadily increased to approximately 460 K.

When heating reached 60 s, the temperature change in the frame gradually stabilized, and the heat distribution on the inner wall became more uniform. This fully demonstrated the stability of the heating process and the evenness of heat distribution.



（a）Heat distribution at 20 s （b）Heat distribution at 40 s （c）Heat distribution at 60 s

Fig. 4 - Heat distribution after heating of the frame

In order to accurately detect the temperature of the frame, based on the characteristics of the temperature change of the inner wall of the frame during the heating simulation, the center of the two sides of the inner wall of the frame and the center of the diagonal were selected as the key detection points for continuous monitoring of the temperature changes. The location distribution of the detection points and the detection results of temperature points are shown in Fig. 5.

（a）The location distribution of the detection points （b）The detection results of temperature points

Fig. 5 - The location distribution of the detection points and the detection results of temperature points

Point 1 was the high temperature point of the inner wall of the frame, and point 2 was the midpoint of the heating of the outer end surface of the seedling tray. Point 3 was the midpoint of the side heating of the seedling tray and was the lowest point of the heat distribution of the whole frame. The simulation time of the three points was 60 s. The temperature changes of point 1, point 2 and point 3 show a linear trend with the heating time. When the heating time was in the range of 0-20 s, the temperature rise of all three points was slow. After the heating time exceeded 20 s, the temperature began to rise rapidly. When the heating time was 60 s, the temperature of point 1 was between 480 K (about 207 ℃) and 540 K (about 267 ℃), which was between 200 ℃ and 270 ℃ in the heating requirement of the inner wall.

Therefore, the heating power of the electromagnetic induction heater was set to 3000 W, and the heating time for the frame at room temperature was set to 60 s, which could meet the heating function requirements of the mold. The infrared camera was used to monitor temperature changes and distribution of the frame. The imaging results of mold heating are shown in Fig. 6.

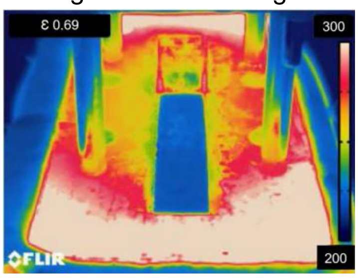


Fig. 6 - The imaging results of mold heating

As can be seen in Fig. 6, heating between 40 s-60 s, the high point temperature of the inner surface of the frame varied from 209 ℃ to 266 ℃, and the low point temperature varied from 174 ℃ to 217 ℃, which was within the range of the glass transition and pyrolysis temperature of lignin. The imaging results of mold heating were basically consistent with the simulation results, and the heating performance of the mold met the heating and compression forming requirements of biomass materials.

Results of biomass seedling trays preparation

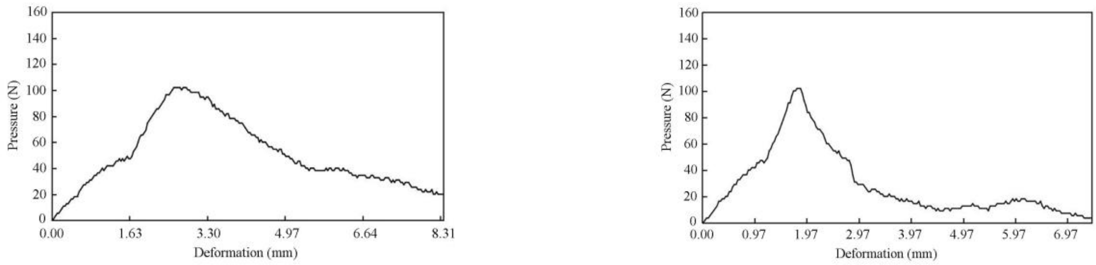
The seedling trays prepared by two different processes, room temperature compression and heating compression are shown in Fig.7. In terms of color characteristics, the heated compressed seedling trays had a slightly darker color compared with the room temperature compressed product. Further micro-analysis revealed that the room-temperature compression trays showed tiny gaps along the sides, generated by friction between the material and the side wall during extrusion - an unavoidable physical phenomenon in the room-temperature compression forming process. The surface of the heated compressed seedling trays exhibited a much smoother quality, making it almost impossible to observe visible imperfections. Therefore, the heated compression process has significant advantages in the preparation of seedling trays and can effectively improve the surface quality of seedling trays.

（a）The room temperature compression （b）The heating compression

Fig. 7 - The seedling trays prepared by two different processes

Results of flexural strength test for seedling trays

The results of flexural strength test for seedling trays of room temperature compression forming and heating compression forming are shown in Fig. 8, the test was repeated 10 times for each treatment.



（a）The room temperature compression （b）The heating compression

Fig. 8 - The results of flexural strength test

When the pressure of the heated compression formed seedling trays reached 100 N, the pressure value dropped rapidly. The room temperature compression formed seedling trays showed a smoother decrease in pressure value when subjected to the same pressure. Although the heated compression formed seedling trays exhibited a greater magnitude of elastic deformation, the difference between the two was not significant in terms of strength.

Results of seedling experiments

After sowing maize in seedling trays, the seeds broke the ground and emerged in 3-4 days and grew to 3 leaves and 1 core in about 18-22 days to meet transplanting requirements. Status of seedling trays at different times after sowing are shown in Fig. 9. None of the seedling trays broke during this seedling cycle, and the maize seedlings grew well.

（a）Status after first watering （b）Status after 5 days （c）State of final growth before transplanting

Fig. 9 - Status of seedling trays at different times after sowing

CONCLUSIONS

In this study, a heating compression forming mold was designed to meet the requirements of forming dimensions and conditions for the preparation of biomass seedling trays for maize transplantation without the addition of adhesives. The preparation of seedling trays, flexural strength test and seedling nursery test were carried out using the designed heating compression forming mold. The surface of the seedling trays was smoother due to the full flow and bonding of lignin during heating compression forming to fill up the gaps caused by friction. The seedling trays obtained by heating compression forming have greater elastic deformation, which improves the elasticity and plasticity of the seedling trays. During the seedling cycle, no rupture occurred in the seedling tray, and the maize seedlings grew well. The designed mold is practical and feasible, and can provide an efficient and environmentally friendly solution for maize seedling transplantation. Lignin, as an important binder, effectively improves the forming effect of seedling trays, which is expected to replace the traditional plastic seedling trays and provide ideas for the resourceful use of agricultural waste.

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