New technology of greening waste to make buffer packaging materials

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Abstract. Developed a new technical solution for making cushioning packaging materials using greening waste as raw materials. Collect greening wastes that have been pruned or fallen off naturally in the city, crushed and sieved, and then alkalized to obtain crude cellulose powder. Through the addition of additives, the foaming is carried out in a microwave manner, and the buffering packaging material is finally made by drying treatment. The material has been verified by the test of cushioning characteristics, has excellent resilience and impact resistance, and is environmentally friendly and degradable. It can replace the non-degradable cushioning materials on the market, such as polystyrene foam (EPS), etc., to reduce environmental pollution.

Keywords: Greening waste, Buffer packaging materials, Microwave foaming.

1. Introduction
Packaging waste is also an important source of solid waste in the city, China's express packaging volume is huge, the existing buffer packaging such as polyphenyl ethylene foam (EPS), foam polyethylene (EPP) and so on, in the manufacturing process will produce pollution, and non-degradable, causing serious harm to the environment. "13th Five-Year Plan" proposed to "accelerate the promotion of green packaging work", we can see that green buffer packaging has broad market prospects.

Based on the above background, the project proposes a technical scheme for green waste buffer packaging materials. Green waste as the substrate, extract the cellulose, and through a series of chemical processes, and finally get green, biodegradable buffer package new materials. The transformation of green waste into green buffer packaging not only reduces the accumulation of urban green waste and packaging waste, but also promotes the transformation of express packaging industry and promotes the promotion of the concept of energy conservation and emission reduction.

2. Technical solutions
The project program process mainly includes 1) pre-treated green waste 2) substrate binder system preparation 3) foaming agent system preparation 4) foam mixing slurry preparation 5) microwave foaming 6) foaming body drying. The concrete steps are shown in Figure 1, first the collected green waste will be pre-treated to obtain cellulose powder backup, and then starch, PVA in accordance with a certain proportion of the configuration of gel solution, after static and stable matrix binder system, and then to cellulose powder Add the substrate binder, foaming agent and additive, stirring and mixing
evenly to obtain a uniform and stable foaming slurry, through microwave foaming way to make the foaming agent in the nucleation point decomposition to produce a stable bubble hole structure, drying to get better mechanics of the buffer packaging material.

**Figure 1.** The overall scenario flow

2.1. Pre-treatment of green waste
Cellulose (C₆H₁₀O₅)ₙ as the main structural component of plant cell walls, the surface presents a multihydroxy characteristics, hydroxyl can be synthesized within the molecule hydrogen bond and the hydrogen bond between the molecules, enhance the linear integrity and rigidity of the cellulose molecular chain, so that the cellulose molecular chain is tightly arranged, showing a highly ordered crystalline region. The interaction of subvalent bond forces between active groups on different cellulose molecules causes the fibers to connect with each other and form a mesh space three-dimensional structure, which becomes the supporting skeleton in the buffer material.

Research shows that the most common types of road trees in Wuhan City are French eucalyptus, camphor, etc., its internal cellulose composition accounted for as shown in the table below.

**Table 1.** Common tree leaf components

| Name of raw material | Cellulose % | Hemicellulose % | Lignin % | Gray % | Other % |
|----------------------|-------------|-----------------|----------|--------|--------|
| French               | 52.43       | 21.20           | 20.65    | 0.42   | 5.30   |
| Camphor              | 53.12       | 20.28           | 21.47    | 0.82   | 4.31   |
| Heather              | 52.55       | 13.95           | 24.76    | 0.36   | 8.38   |
| Poplar               | 51.86       | 16.08           | 28.42    | 0.33   | 3.31   |

This project selects the pruning of the French dates as raw material, breaks it into powder in the crusher, sieves for 70 eyes, gets the initial powder, and then heats it into a 16% NaOH solution to 60 degrees Celsius and stirs 2h for alkalinization, dissolves impurities such as pectin, ash, lipids, and reduces the crystallization of cellulose and increases its long-diameter ratio. At this time in the surface
of cellulose appeared a lot of shallow grooves, fiber and substrate binder mechanical binding force increased, dispersion increased, interface binding effect significantly improved;

![Figure 2. Pre-treatment of green waste](image)

2.2. Substrate binder system

The function of the substrate binder is to bond the fiber skeleton and other additives scattered in the foaming system to form a structure with a certain strength. The substrate binders for this project are a compound of starch and polyethylene alcohol (PVA). Configure a starch solution with a quality score of 30%, pre-paste in a heated water bath at 65 degrees C for a period of time, the starch molecules are entangled with each other to form a space mesh water-containing colloid with good thermoplasticity. As shown in Figure 5(a), configure a 7.5% PVA solution and stir the fluid-efficient colloids in a 95-degree heated water bath, as shown in Figure 5(b); The co-mixing of the midhydroxyl group and starch molecules in the VA molecular structure is beneficial to the paste of starch particles embedded in the PVA molecular system to form a better compatibility, continuous distribution of the two-phase structure, and then has good bonding and elongation, so that the final foam body has better strength and elasticity.

![Figure 3. Adhesive system](image)

The properties of the substrate binder have an important influence on the molding of the material, the experimental stage, the configuration of different proportions of starch / PVA reagents, each proportion of formula preparation 3 specimens for foaming experiments, to observe the effect of different ratios on the molding effect of the buffer material, to obtain the best formulation ratio, the results of the experiment can be seen in Table 2.

| The experiment number | Starch /PVA | Sample molding effect                          |
|-----------------------|-------------|-----------------------------------------------|
| 1                     | 1:1         | The base strength is insufficient and prone to collapse |
| 2                     | 1:1.5       | The molding effect is good, and there is better elasticity |
| 3                     | 2:1         | After the material is dried, the whole is hard and less elastic |
Through comparative experimental analysis, it can be seen that the starch ratio is too high will lead to the material hard, PVA ratio will lead to insufficient material strength, and finally this project selected starch : PVA for 1:1.5 configuration of the substrate binder, the resulting buffer packaging material molding effect is best and has better resilience.

2.3. Foaming agent system
Foaming agents break down and release gases as they rise in temperature during foaming, causing bubble hole structures to form in polymers. The project uses chemical foaming to combine azodiamine AC(C₂H₄N₄O₂) with NaHCO₃ and add ZnO as the activator of AC. Among them, ZnO is better at 0.1g, reducing the decomposition temperature of AC from 195-210 degrees C to 130 degrees C, and the entire foaming agent system rises to temperature by mixing with NaHCO₃ at a decomposition temperature of 60-150 degrees C. Steady foaming begins at 80 degrees C, forming a stable foaming material with uniform foaming holes that are not easy to collapse. AC belongs to the heat release type foaming agent, while NaHCO₃ belongs to the heat-absorbing foaming agent, the two work together to cool the base and stabilize the foaming hole structure throughout the foaming process. Finally, the pores are uniform and the buffer packaging material with better cushioning performance is obtained.

Table 3. The effect of the ratio of two foaming agents on the buffer packaging material

| The experiment number | AC/ NaHCO₃ | Sample molding effect |
|----------------------|------------|-----------------------|
| 1                    | 1:1        | The bubble hole is large, easy to collapse, and the density is small |
| 2                    | 1:1.5      | The bubble holes are uniform and the buffering effect is good |
| 3                    | 2:1        | The material as a whole is hard, the bubble holes are fewer, and the buffering effect is poor |

Figure 4. Effect of the amount of composite foaming agent on the buffer material

Through experiments, when the compound foaming dose is less, the foam hole is less, the buffer effect is poor, more time, the bubble hole is larger and easily collapsed, and the compound foaming agent with 1.0g of AC: NaHCO₃ is 1:1.5, the amount of decomposition and release of gas during the foaming process can meet the needs of the bubble distribution, so that the material shows excellent buffering performance.

2.4. Preparation process for buffer packaging materials

2.4.1. Preparation of foam mixtures. After the pre-treatment of green waste and the preparation of binders, the extracted cellulose and foaming agent, nucleator and crosslinker and other solid powders are mixed and stirred proportionally, so that the components are evenly dispersed into the foaming body to ensure the consistency of each part of the foaming body characteristics; Among them, the addition of each ingredient and the quality score are shown in the table below.
Table 4. The proportion of various components of the foaming system

| ingredients     | The amount added | Quality score |
|-----------------|------------------|---------------|
| Cellulose powder| 5g               | 36.23%        |
| Adhesives       | 3.5g             | 25.36%        |
| Blowing agent   | 1g               | 7.24%         |
| glycerol        | 3g               | 21.73%        |
| talcum powder   | 0.3g             | 2.17%         |
| VAE             | 0.5g             | 3.62%         |
| borax           | 0.5g             | 3.62%         |

2.4.2. The formation of the buffer material. The configured mixing slurry into the molding mold, sealed and placed in the microwave oven for foaming, microwave foaming, first adjust the foaming temperature to 70 degrees C foaming for 2 minutes, foaming agent began to gradually decompose, in the polymer melt to form a large number of bubble cores, and then the bubble core expanded into a foaming body. Continue to adjust the temperature to 110 degrees C for 2 minutes, and as the temperature rises, the foam continues to expand to complete the foaming. Then the foam body will be completed foaming into the drying tank to dry quickly, along with the evaporation of water, into the bubble hole's curing and shaping stage, bubbles are surrounded by a solid shell, the overall pressure gradually balanced, and finally bubble hole structure formation, to obtain a buffer performance of excellent porous buffer material.

3. Buffer material performance test

3.1. Static compression test of buffer material

This experiment uses the cardboard pressure tester as a static test instrument to buffer the material, and the stress-strain graph of the buffer material is obtained by pressurized, as shown in Figure 9 (a). Take a point in the curve, the stress is $\sigma_m$, the strain is $\varepsilon_m$, and the area of the curved triangle with that point as the vertex is the elasticity of the material must be $u$:

$$u = \int_0^{\varepsilon_m} \sigma d\varepsilon$$  \hspace{1cm} (1)

The buffer factor corresponding to this point is:

$$C = \frac{\sigma_m}{u} = \frac{\int_0^{\varepsilon_m} \sigma d\varepsilon}{\int_0^{\varepsilon_m} \sigma d\varepsilon}$$  \hspace{1cm} (2)

Based on the formula (2), the buffering factor of the material is obtained, and the buffering factor of the material is plotted - the maximum stress (C-m)$\sigma$ curve is shown in Figure 9(b).
Buffering factor - The maximum stress curve is widely used and is an important reference for packaging design. According to the curve, the buffer coefficient decreases gradually as the stress increases and decreases to 6, i.e., the minimum buffer coefficient of the material is around 6 and the buffer performance is better. As shown in Figure 10, for the two commonly used buffer packaging material C-\sigma curve, from the figure can be seen foaming polystyrene minimum buffering factor value of about 4, foaming polyethylene minimum buffer coefficient of about 5.7, the minimum buffer coefficient of material specimens compared with the current domestic main buffer packaging materials, the value difference is not much, buffer performance is similar.

3.2. Dynamic test of buffer material

The dynamic test is carried out on the hammer impact machine, as shown in Figure 11, the rising hammer falls to the preset height H for free fall, a shock on the specimen buffer material with a thickness of hand an area of A, and an accelerometer measures the maximum acceleration a for each impact of the hammer. It is known that W, H, A, and a can get \( \sigma \) and C, and thus a point on the maximum stress curve of the buffer coefficient, that is

\[
\sigma_m = \frac{G_m W}{A}
\]

The drop height of each test remains the same as the thickness of the test piece, and by constantly changing the mass W of the hammer, the corresponding maximum acceleration \( G_m \sigma_m \) is measured, and the points on the Gm-m curve can be obtained by the formula (3), and the connected curve is the

![Figure 5. Static test of the buffer material](image)

![Figure 6. C-m curve of other \( \sigma \) buffer materials](image)
maximum acceleration of the material - the static stress curve, as shown in Figure 12. As can be seen from the figure, the buffer material has excellent cushioning performance under the impact.

![Figure 7. Hammer impactor](image)

![Figure 8. Maximum acceleration of the buffer material - static stress curve](image)

4. Conclusions
This technology can effectively improve the recycling utilization rate of green waste, improve product value, can be applied to urban garden waste recycling system, promote the construction of "beautiful city". At the same time, this buffer packaging material has good physical properties and a variety of molding methods, can be suitable for a variety of different needs of the buffer packaging. At present, the international community has formulated a more perfect green packaging system, which has become an important factor affecting China's foreign trade, if the material is popularized and applied, it can solve the problem of green packaging barriers to china's product exports to a certain extent, promote the green development of the entire packaging industry, in line with the development trend of international green manufacturing.

References
[1] Yang Wenling, Wang Yu tea Corn straw cellulose extraction process optimization.. Anhui Agricultural Science, 2019, 47 (01): 198-201
[2] Fang Qi. Study on buffering properties of buffer packaging materials.. Tianjin University of Science and Technology, 2013
[3] Wang Fang, Li Hongyuan Green waste resource utilization and prospects... China Development, 2014, 14 (01): 5-11
[4] Jiang Yushan. Study on the economic use of landscaping waste and its management of recycling and utilization. China's forestry economy, 2021 (03): 70-72.
[5] Gu Yalan. To explore the ways of landscaping plant waste disposal and resource utilization under the new situation. Modern horticulture, 2021, 44 (03): 124-126.
[6] Kang Kaili, Wang Park, Xia Yuxuan, Liang Yuxuan, Yu Jingya. China's landscaping waste resource utilization methods and recommendations. Tianjin Agricultural Science, 2021, 27 (02): 87-90