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Title: Twin-Screw Extrusion Process to Produce Renewable Fiberboards

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Author Questionnaire

1. Microscopy: Does your protocol demonstrate the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or similar? **No**

2. Software: Does the part of your protocol being filmed demonstrate software usage? **No**

3. Interview statements: Considering the Covid-19-imposed mask-wearing and social distancing recommendations, which interview statement filming option is the most appropriate for your group? **Please select one**.

☒ Interviewees wear masks until the videographer steps away (≥6 ft/2 m) and begins filming. The interviewee then removes the mask for line delivery only. When the shot is acquired, the interviewee puts the mask back on. Statements can be filmed outside if weather permits.

3. Filming location: Will the filming need to take place in multiple locations (greater than walking distance)? **No**

Protocol Length
Number of Shots: **35**

Introduction

1. Introductory Interview Statements

REQUIRED:

1.1. **Philippe Evon**: This twin-screw extrusion technology can be used to continuously and efficiently conduct the pretreatment of lignocellulosic biomasses into a homogeneous thermo-mechanical pulp prior to fiberboard molding **[1]**.

1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

REQUIRED:

1.2. **Philippe Evon**: The pulps are produced at low cost using a reduced volume of water and the versatility of the extrusion allows the addition of a binder to the refined fibers in a single pass **[1]**.

1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

OPTIONAL:

1.3. **Antoine Rouilly**: Using a combined temperature/moisture content is key for a successful twin-screw extrusion of the lignocellulosic fibers. Always start with an excess of water and then decrease the amount until the desired texture is obtained **[1]**.

1.3.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

OPTIONAL:

1.4. **Antoine Rouilly**: As this process is very sensitive, it is crucial to rely on all of the senses. The video adds sight and hearing to the paper. Smell and Touch in the near future **[1]**?

1.4.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

Introduction of Demonstrator on Camera

1.5. **Philippe Evon**: Demonstrating the procedure will be Laurent Labonne, an Engineer from my laboratory. Laurent will be assisted by Saif Ullah Khan, a PhD student in the lab **[1][2]**.

1.5.1. INTERVIEW: Author saying the above

1.5.2. The named demonstrator(s) looks up from workbench or desk or microscope and acknowledges the camera

Protocol

2. Twin-Screw Extruder Preparation

2.1. Begin by using half clamps to connect the twin-screw extruder modules in the correct configuration for fiber defibration only **[1-TXT]**.

2.1.1. WIDE: Talent clamping modules **TEXT: Alternative: Set up configuration with addition of natural binder**

2.2. Position the water inlet pipe laterally at the end of module 2 to connect the piston pump to the machine **[1]** and check the screw element type, length, pitch, and staggering angle **[2]**.

2.2.1. Talent position pipe/connecting pump to machine
2.2.2. Talent checking screw element(s)

2.3. Insert the screw elements along the two splined shafts in pairs **[1]**, taking care that the threads of each inserted screw element are always perfectly aligned with the previously assembled elements **[2]**.

2.3.1. Element(s) being inserted *Videographer: Important/difficult step*
2.3.2. Shot of threads aligned with other threads *Videographer: Important/difficult step*

2.4. Once the entire screw profile has been assembled, manually screw the screw points at the ends of the two shafts **[1]**, completely close the barrel of the machine **[2]**, and use a torque wrench to tighten the two screw points to the tightening torque recommended by the manufacturer **[3]**.

2.4.1. Talent manually screwing screw point
2.4.2. Talent closing barrel
2.4.3. Talent using wrench to tighten screw point

2.5. With the barrel of the machine partially reopened and the shafts retracted into the barrel over a distance of approximately 1 dimension, turn the screws at a maximum of 25 revolutions per minute to ensure that the entire screw profile is correctly fitted **[1]**.

2.5.1. Shot of shafts retracted, then screws being rotated *Videographer: Important step*

2.6. When both shafts have been entirely trapped inside the barrel, use half clamps to secure the barrel to the machine **[1]** and use a level tester to confirm that the barrel is perfectly horizontal **[2]**.

2.6.1. Barrel being closed/clamped
2.6.2. Level being checked

3. Twin-Screw Extrusion Treatment

3.1. For twin-screw extrusion treatment, enter the set temperatures of each of the modules **[1]** and start the temperature control of the barrel **[2]**.

3.1.1. WIDE: Talent entering temperatures, with monitor visible in frame **TEXT: See text for temperature setup details**
3.1.2. Talent starting temperature control

3.2. When the temperature has stabilized, turn the screws at a maximum of 50 revolutions per minute **[1]** and gently feed the twin-screw extruder with water at a flow rate of 5 kilograms/hour **[2]**.

3.2.1. Screw(s) being turned
3.2.2. Extruder being fed water

3.3. Wait about 30 seconds for water to come out of the end of the barrel **[1]** before introducing the oleaginous flax shives into module 1 at a 3 kilogram/hour-flow rate **[2]**.

3.3.1. Shot of end of barrel, then water coming out
3.3.2. Shives being introduced

3.4. Wait about 1 minute for the solid to begin coming out of the extruder **[1]** before gradually increasing the speed of the screws, water, and shive flow rates **[2-TXT]** in at least three success steps until the desired set points have been reached **[3-added]**.

3.4.1. Shot of end, then solid coming out *Videographer: Important step*
3.4.2. Screw speed and/or water and/or shive flow rate being increased *Videographer: Important/difficult step* **TEXT: screws: 150 rpm; water: 15 kg/h; shives: 15 kg/h**
3.4.3. Added shot: Shot of end with screw speed, water flow rate and shives flow rate at their set values (150 rpm, 15 kg/h and 15 kg/h, respectively)

3.5. Allow the machine to stabilize for 10-15 minutes until the electrical current consumed by the engine over time varies no more than 5% from the 125-amp average value **[1]**.

3.5.1. Shot of electrical current output

3.6. For the addition of natural binder, once the machine has stabilized, begin introducing the plasticized linseed cake at rate of 0.5 kilograms/hour **[1]**.

3.6.1. Cake being introduced

3.7. Then increase the flow rate in at least three successive steps up to the desired set point **[1]**.

3.7.1. Flow are being increased *Videographer: Important step*

3.8. Once the electrical current consumed by the twin-screw extruder motor is perfectly stable, make sure that the temperature profile measured along the barrel conforms to the set values given by the operator **[1]** and start sampling the extruded shives at the outlet **[2]**.

3.8.1. Talent checking temperature profile
3.8.2. Shives being sampled

3.9. At the end of production, switch off the two solid dosing units and the piston pump **[1]** and empty the machine while gradually reducing the speed of the rotation of the screws to 50 revolutions per minute **[2]**.

3.9.1. Talent turning off units and/or pump
3.9.2. Talent emptying machine while reducing rotation speed

3.10. When no additional sampling is coming out of the barrel end, use water to clean the inside of the barrel of the twin-screw extruder while the screws are still rotating **[1]** until the solid residues disappear completely at the outlet of the barrel **[2]**.

3.10.1. Talent cleaning inside of barrel
3.10.2. Residue(s) disappearing at barrel outlet

3.11. Then stop the rotation of the screws **[1]** and switch off the heating control of the machine **[2]**.

3.11.1. Talent stopping screw rotation
3.11.2. Talent switching off heating control

4. Extrudate Drying and Fiberboard Molding

4.1. Immediately after the twin-screw extrusion process, dry the extrudates with hot air flow to a humidity between 3% and 4% **[1]**.

4.1.1. WIDE: Talent drying extrudates

4.2. When the extrudate has dried, position the material in a pre-heated mold **[1]** and pre-heat the material **[2]**.

4.2.1. Talent placing material into mold *Videographer: Important step*
4.2.2. Talent pre-heating material *Videographer: Important step*

4.3. After 3 minutes, apply the appropriate amount of pressure to the material **[1]** and mold the material for 150 seconds at the 200 degrees Celsius already set up **[2-TXT]**. Once the press is opened, demold the panel and then check its cohesion **[3-added]**.

4.3.1. Talent setting/applying pressure *Videographer: Important step*
4.3.2. Once the press is opened, demold the panel.
4.3.3. Added shot: Check the cohesion of the panel once obtained.

Protocol Script Questions

A. Which steps from the protocol are the most important for viewers to see? Please list 4 to 6 individual steps.
2.3., 2.5., 3.4., 3.7., 4.2., 4.3.

B. What is the single most difficult aspect of this procedure and what do you do to ensure success? Please list 1 or 2 individual steps from the script above.
2.3., if the screw elements are not inserted well in pairs along the two splined shafts, this will cause abrasive wear on the screw elements and/or the inner walls of the barrel. The success of this step is attained by visual inspection (step 2.3.2.), and then by turning the screws at a maximum 25 rpm screw rotation speed with the barrel of the machine partially opened (step 2.5.).
3.4. is attained by controlling the evolution of the electrical current consumed by the engine over time. During step 3.4.2., its increase must be controlled.

Results

5. Results: Representative Renewable Fiberboard Production and Analysis

5.1. Following the extrusion-refining pre-treatment **[1]**, the chemical composition of the extrusion-refined fibers can be determined **[2]**.

5.1.1. LAB MEDIA: Table 3
5.1.2. LAB MEDIA: Table 3 *Video Editor: please emphasize ERF column*

5.2. In the absence of liquid extract generation during the extrusion-refining pre-treatment **[1]**, no significant difference in chemical composition was observed between the raw shives and the extruded ones **[2]**.

5.2.1. LAB MEDIA: Table 3
5.2.2. LAB MEDIA: Table 3 *Video Editor: please emphasize both OFS and ERF columns*

5.3. In terms of appearance **[1]**, extrusion-refined fibers have a fluffy material form, indicating that the extrusion process, in particular the high shear rate applied, contributes to a modification of the flax shives structure **[2]**.

5.3.1. LAB MEDIA: Figure 3
5.3.2. LAB MEDIA: Figure 3 *Video Editor: please emphasize bottom left material image*

5.4. This is first confirmed **[1]** by the lower apparent and tapped densities of the extruded shives **[2]** compared to the values obtained with the raw shives **[3]**.

5.4.1. LAB MEDIA: Table 4
5.4.2. LAB MEDIA: Table 4 *Video Editor: please emphasize ERF row*
5.4.3. LAB MEDIA: Table 4 *Video Editor: please emphasize OFS row*

5.5. Morphological analysis of the fibers also confirms this observation as a very significant increase in their aspect ratio using a fiber morphology analysis device **[1]**.

5.5.1. LAB MEDIA: Table 5 *Video Editor: please emphasize Aspect ratio column*

5.6. Boards made from extruded fibers alone **[1]** without the addition of plasticized linseed cake as an external binder **[2]** are not only all three cohesive but above all present significantly improved usage properties compared to boards obtained by hot pressing of the raw shives **[3]**.

5.6.1. LAB MEDIA: Table 6
5.6.2. LAB MEDIA: Table 6 *Video Editor: please emphasize columns 1, 3, and 7*
5.6.3. LAB MEDIA: Table 6 *Video Editor: please emphasize columns 11 and 12*

5.7. Overall, the addition of plasticized linseed cake to the extrusion-refined fibers increases the flexural properties of the fiberboards obtained **[1]**.

5.7.1. LAB MEDIA: Table 6 *Video Editor: please emphasize columns 2, 4, 5, 6, 8, 9, and 10*

5.8. Indeed, with the addition of 25% of this binder, the obtained board has a flexural strength of 10.6 megapascals instead of only 3.6 **[1]**.

5.8.1. LAB MEDIA: Figure 4 *Video Editor: please emphasize top right board image*

Conclusion

6. Conclusion Interview Statements

6.1. **Philippe Evon**: For process intensification, the fiber refining and binder addition can be performed in a single pass. The process will adapt to all types of raw materials **[1]**.

6.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera (3.5., 3.8.)

