University of Maribor

# Novel textile technologies
# 3D shaped cellulose based disposable packaging made with the DryThermoforming process - a combination of technologies

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Private academic consultant
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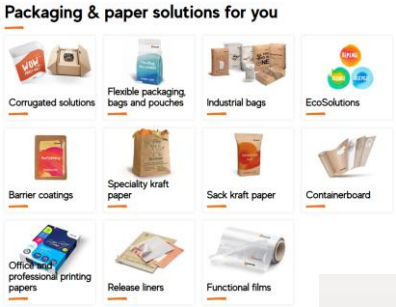
# Introduction

## Dr. Johannes Leitner

- Applied Science Manager at Mondi (Link)
- Guest lecturer at various national and international universities
  - Paper and Packaging Technology
  - Fiberbased building materials and circular economy
  - Nonwovens technology and textile recycling
    - More to find on linked in (Link)
- Education in Austria & international:
  - Wood and natural fiber technology at BOKU Vienna (Link)
  - Chemical Engineering at Technical University Graz (Link)
- Motivation: working together
  - Sharing my hands for sustainable solutions in & between industries

# Mondi‘s slogan: paper when possible and plastic when needed





Woven polypropylene


Replace shrink film

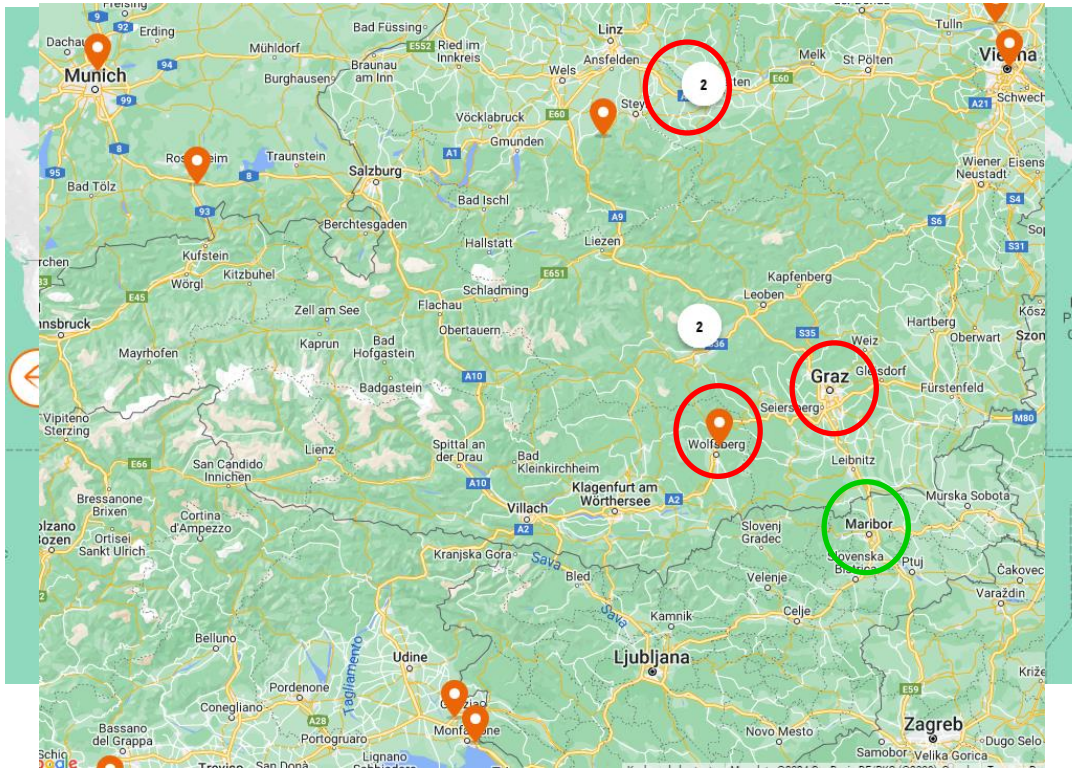

Replace stretch film

Replace PET Tray

ALL INNOVATIVE PRODUCTS ARE RECYCLABLE

# Mondi

- International pulp and packaging company with operations close to Slovenia




## Mondi Group

**(www.mondigroup.com)**

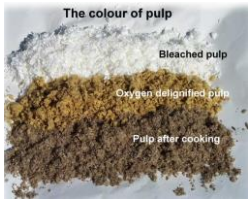
- Europe and South Africa
- 11 pulp and papermills producing 4 million tons p.a.
- 2 important mills nearby:
  - New!!Duino mill in Italy for Containerboard
  - Frantschach (Wolfsberg)
- R&D centers
- Graz
- Frantschach
- Hausmening

→collaborate with Mondi in the form of bachelor-, master and PhD thesis and drop an email to johannes.leitner@mondigroup.com

# How can you interact with Mondi?

- Bachelor thesis
  - Pulp and fiber technology as well as surface treatment
  - Chemical engineering and chemistry - Depolymerization of resins under different conditions (pH, temperature, time) and stabilization with chemicals after the depolymerization
- Master thesis

small scale rotating digester for pulping




larg scale rotating pulper

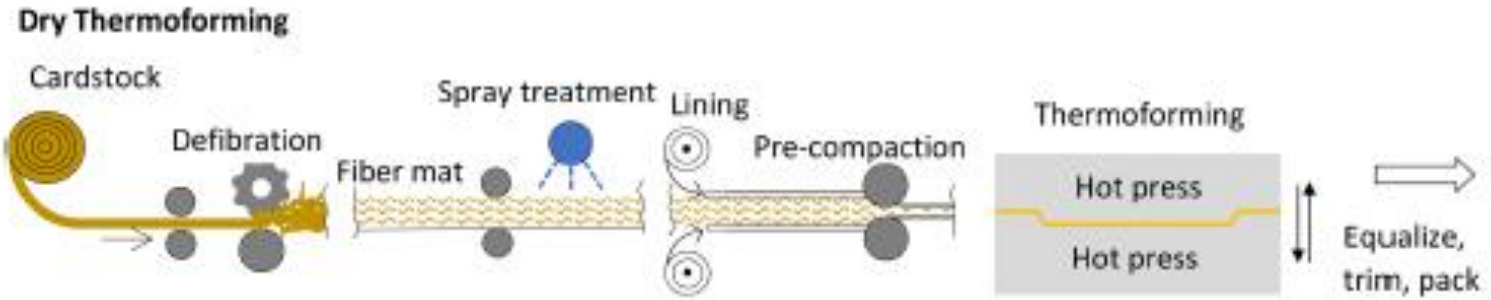
- Internships - and Master thesis
  - At Mondi Labs Graz, Hausmening or in Frantschach
  - Typically for 2 months
    - Check out here or contact via email
    - https://www.mondigroup.com/careers/available-jobs/

# Agenda

- Replacing single use plastics with cellulose

- Wetlaid 3D shaped disposable products


- Drylaid 3D shaped disposable products
  - Pulping and Fluff Pulp Technology
  - Manufacturing of nonwovens
  - 3D Moulding



# Stop Single Use Plastics

## EU-Single Use Plastic Directive:

### Challenges may be turned into opportunities


- Opportunities for 3D shaped cellulose disposable materials

# Stop Single Use Plastics

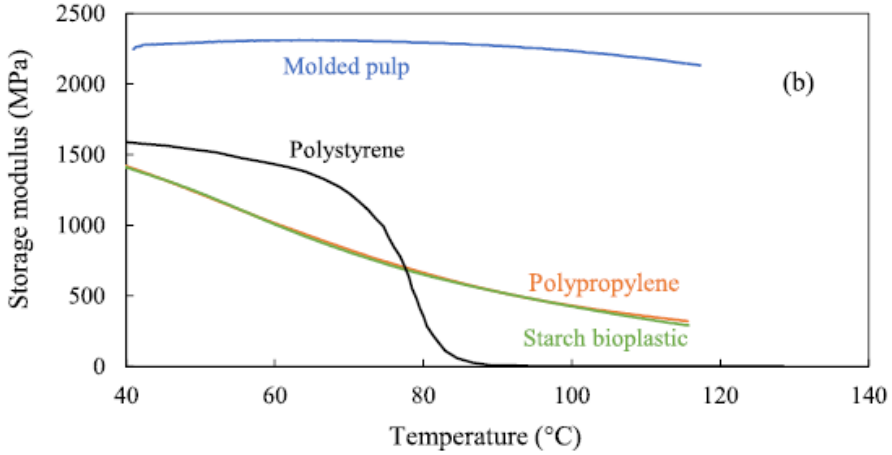
## EU-Single Use Plastic Directive:

- Covid19 boosted the capacities for cellulose based cup lids and Clamshalls with optimal thermal insulation, water and grease resistance and recyclability

# Wetlaid Single Use Food Containers

**Requirements to**

- Cost efficient process (energy, raw materials, productivity)
- Recyclable
- Thermal insulation
- Resistant to hot beverages





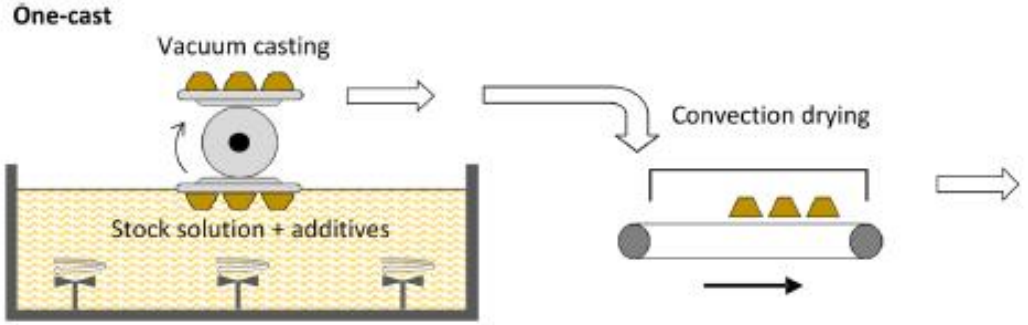

Dr. Johannes Leitner I **Private academic consultant**

Source: Semple et al 2022 in Food Packaging and Shelf Life 33 (2022)

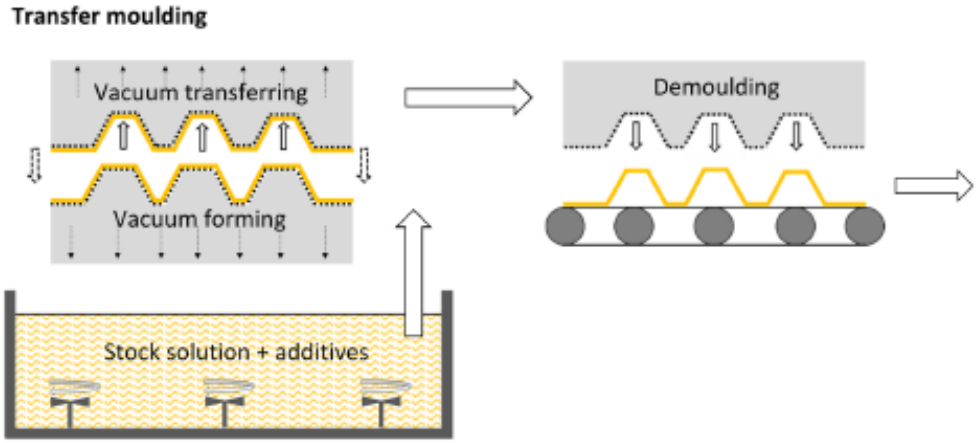
# Process Technologies

## Wet- and Drylaid Processes

- One-Cast:




- Transfer Moulding



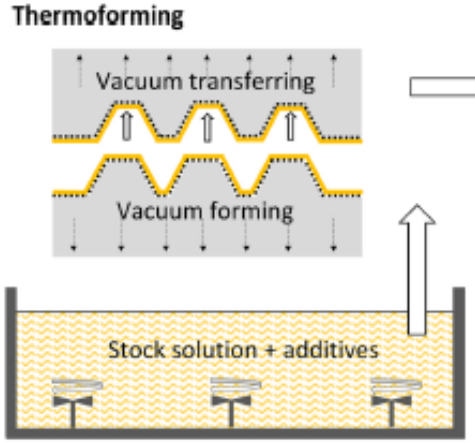


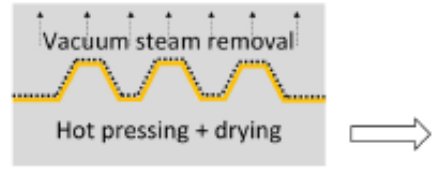

Source: Semple et al 2022 in Food Packaging and Shelf Life 33 (2022)

# Process Technologies

## Wet- and Drylaid Processes

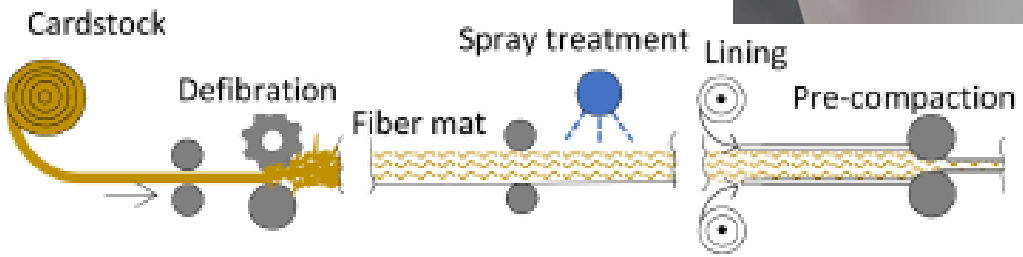
- Thermoforming:

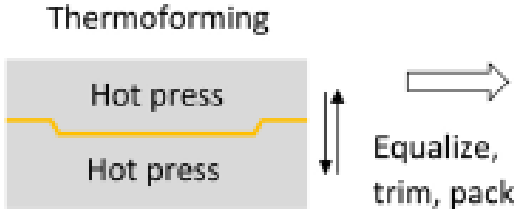



Equalize, trim, pack

- Dry Thermoforming




Equalize, trim, pack



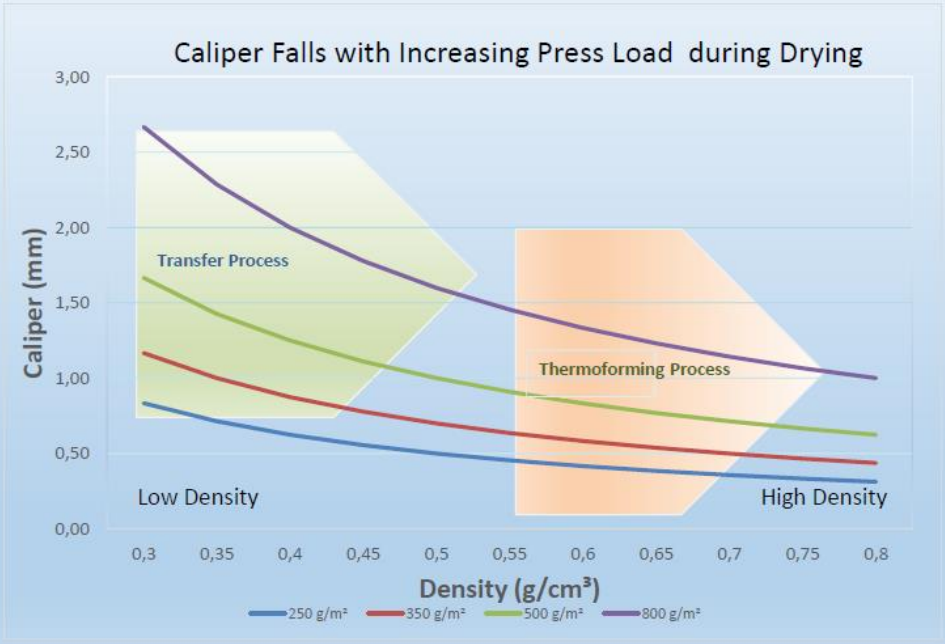
Source: Semple et al 2022 in Food Packaging and Shelf Life 33 (2022)

# Wetlaid Single Use Food Containers

## Wetlaid processes – different process technologies

**Difference between Transfer-Process and Thermoforming-process**

Rough surface




Smooth suface

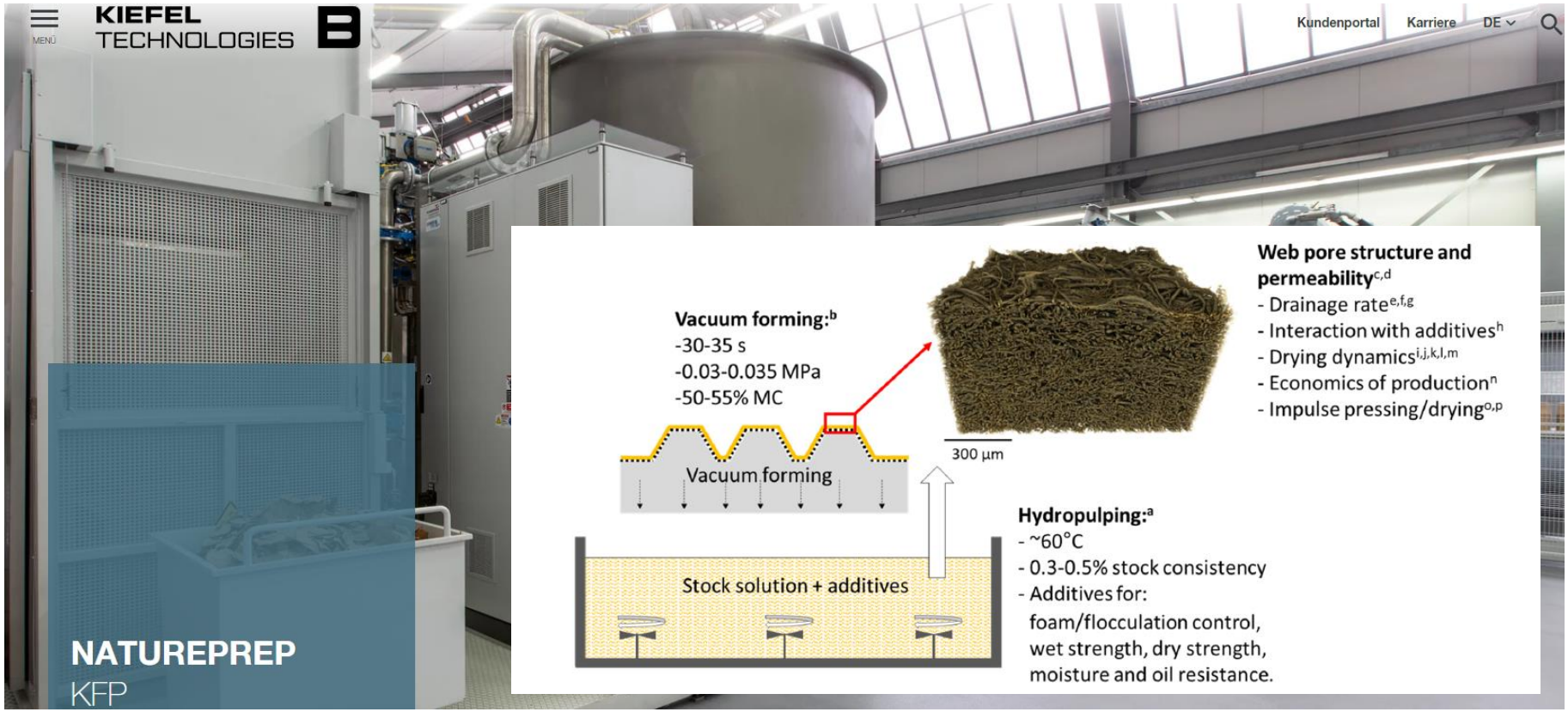
PAYR Engineering GmbH . PAYR Production GmbH
engineering@payr.co.at . production@payr.co.at

Folie 10 www.payr.co.at

# Wetlaid Single Use Food Containers

## Wet- and Drylaid Processes

– Unit operation – a pulp chest and mutliple forming stations




Source: Semple et al 2022 in Food Packaging and Shelf Life 33 (2022)

# Wetlaid Single Use Food Containers

## Wetlaid Processes

- Pulp Types
  - Recycled pulp from newspapers suffer from high fines content
  - Kraftpulp is known for it‘s high fiber bonding potential but expensive
  - Bleached mechnaical pulp (BCTMP) is a good (relation price & value

- Process Performance additives
  - pH regulator and fixative - typically aluminium sulfate
  - Retention aid – typically cationic Poly Aycryl Amide (PAM)
  - Antifoaming – typically surfactants
  - Bonding agent – cationic starch
  - Hydrophobic sizing – Alkyl Succinic Acid (ASA) and Alkyl Ketene Dimers (AKD) resin, natural wood based rosin size
  - Oil and grease resistance – PFAS free
  - Barriere Liners – typically PET film or



Source: Semple et al 2022 in Food Packaging and Shelf Life 33 (2022)

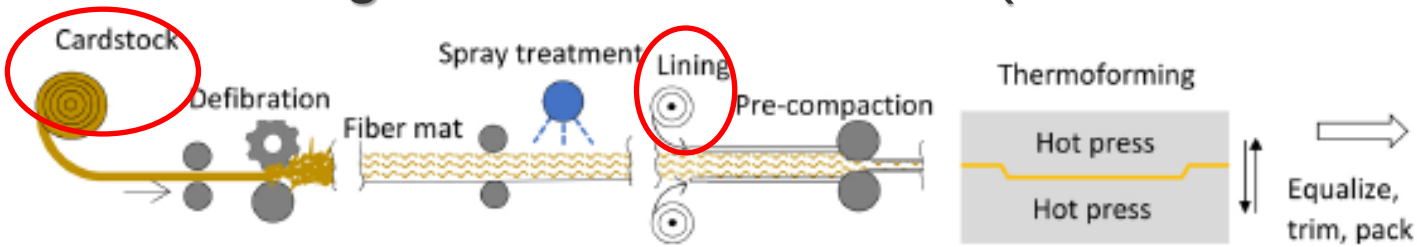
# Wetlaid Single Use Food Containers

## Wet- and Drylaid Processes

- Productivity

| Process | Cold press time in sec | Hot press time in sec | Hot press temperature in °C | Ref |
|---|---|---|---|---|
| Wet Thermoforming | 25 – 30 | 45 - 120 | 185 - 220 | Liu 2020 Dislaire 2021 |
| Dry Thermoforming | | 3,5 – 5 | 160 | Wang et al 2021 |

- Dry Thermoformed process has higher productivity but also higher raw material cost (cardstock & lining)





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Source: Semple et al 2022 in Food Packaging and Shelf Life 33 (2022)

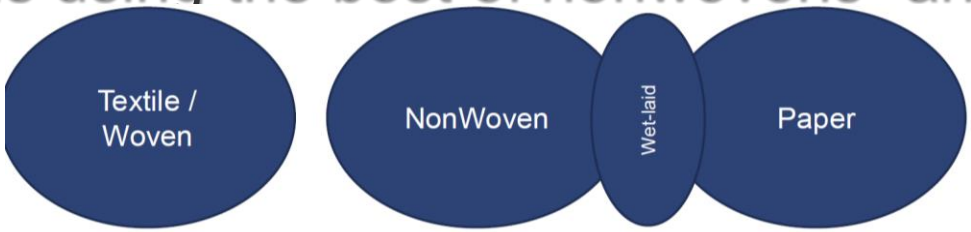
# Drylaid Single Use Food Containers

## PulPac Process (www.pulpac.se)

# DryThermoforming

## Background & outlook of the technology

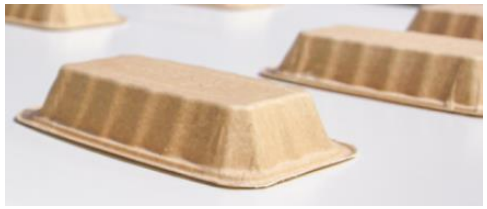
- Pulpac‘s technology is using the best of nonwovens- and paper technology




Raw materials & Stock preparation

Hot pressing technology

- Technology Outlook:
  - Pulpac only holds & develops the technology
  - Several OEMS produce the units (USA, EU, ASIA)
  - List of installations – an incomplete snapshot:
    - Biolutions – focused on agricultural low cost raw materials and teamed up with Xelfo Technologies
    - Matrix Pack for cup lids
    - Haleon for medical blister pack

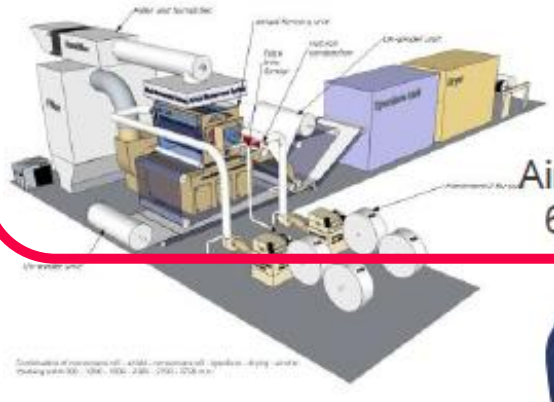



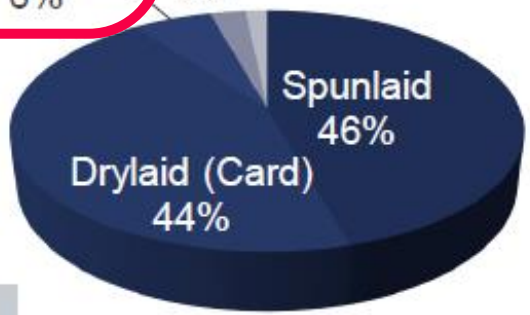
# DryThermoforming

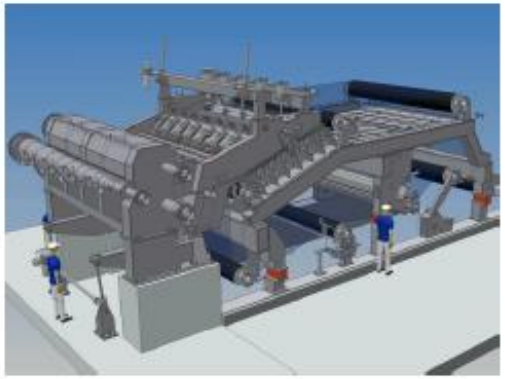
## Origin of the DryThermoforming Technology

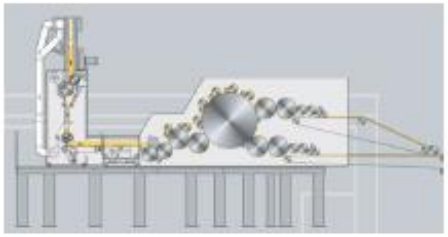
Web forming
The nonwovens world forms dry

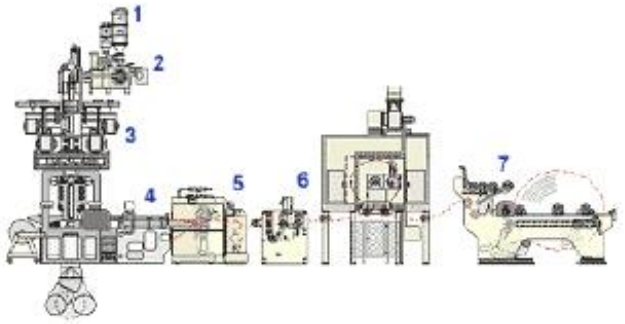
VOITH









# DryThermoforming

## Airlaid Products – niche and large volume markets for day-to-day use

| | | |
|---|---|---|
| High grade table top products |   | ▪ Napkins<br>▪ Table cloths |
| Wiping products |   | ▪ Wet wipes<br>▪ Baby wipes<br>▪ Wet toilet tissue<br>▪ Cosmetic wipes |
| Feminine hygiene products |    | ▪ Sanitary napkins<br>▪ Panty shields |
| Household cleaning |     | ▪ Kitchen rolls<br>▪ Floor cleaning |
| Industrial applications |   | ▪ Industrial wipes<br>▪ Meat packaging |
| Incontinence products |     | ▪ Absorbent cores for Incontince Products<br>▪ Bed sheets |
| Health care and hospital products |   | ▪ Wash glowes and bed covers<br>▪ Absorbent cores for wound care |

# DryThermoforming

## Rawmaterials

- Fluff pulp in reels significantly differentiates from paper pulp by it‘s delivery form
  - Fluff pulp in reels is easier to dose to hammer mills
  - Rare specialities supply flash dried pulp to textile industry
- Fluff pulp is commonly bleached softwood pulp but specialities exist:
  - Unbleached pulp (UPM)
  - Hardwood pulp (Suzano, Ence)
  - HT-BCTMP pulp in rare occasions


Papere Pulp in bales


Sheet dried


Flash dried dried


Fluff pulp in reels

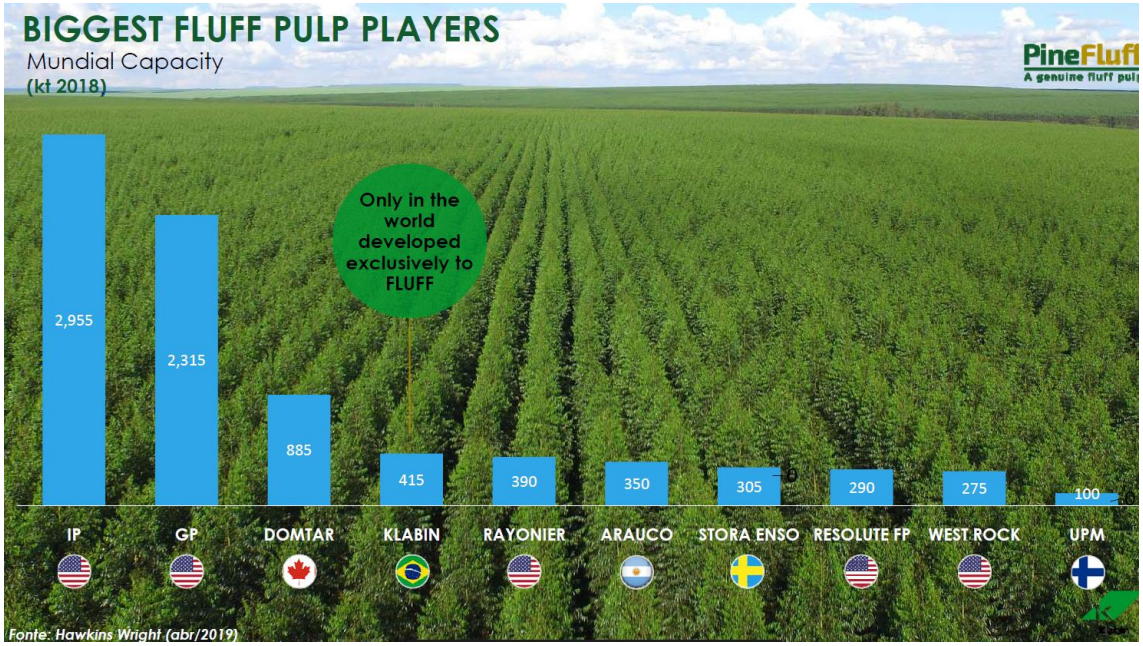

Coils of sheet dried pulp


Fluff pulp specialities are unbleached fluff pulp

Pulpac is interested in unbleached flash dried pulp, but ….

# Fluff Pulp Technology

## Largest manufacturer are in the US and in South America



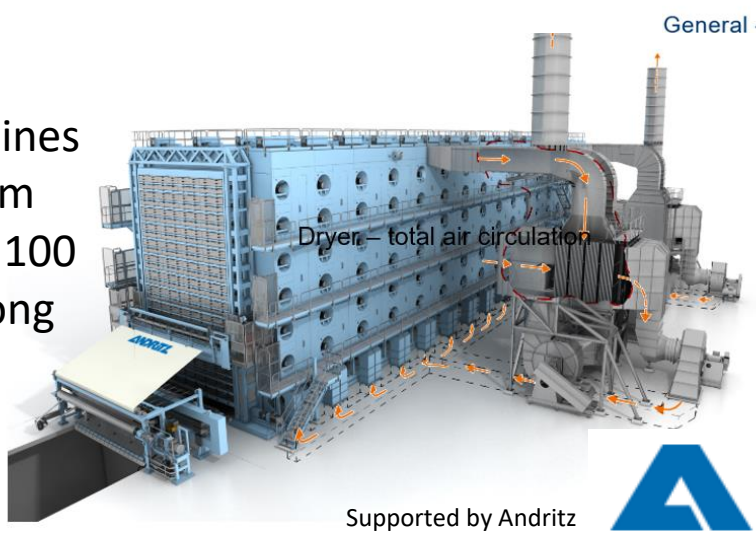

- Main Raw Material is (Southern/Radiata) Pine:
  - Suzano and Ence disrupt the market with short fiber eucalyptus at lower cost due to it‘s high yield and fast rotation time in plantations

# Fluff Pulp Technology

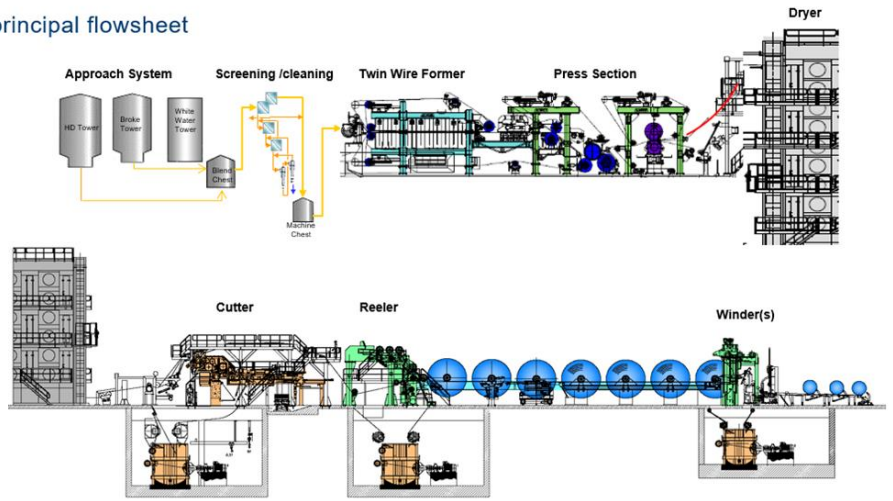
## Manufacturing of Fluff Pulp

- Kraft pulp mills with conventional bleaching but specific process conditions and chemicals dosed to the pulp dryer
- Winder & wrapping(for reels) instead of a layboy (for sheets)
- Reels are transported to the airlaid nonwovens plant

Big machines up to 20 m high and 100 meters long




Supported by Andritz



# Fluff Pulp Technology

## Quality parameters of fluff pulp

- Lower basis weight of fluff pulp in reels: ~ 700 g/m² compared to >1000 g/m² of paper pulp in bales
- Good Formation is important for hammer milling
- Designed low mullen burst strength of 600 – 1300 kPa, which is affected by the pulps low density between 550 and 650 kg/m³
- Low extractives content is important for hygiene applications in diapers for babies and adults

# DryThermoforming

## Process steps

- Main processe in brief overview:

Short fiber Fluff pulp in reels
0,8 – 2,5 mm fiber length

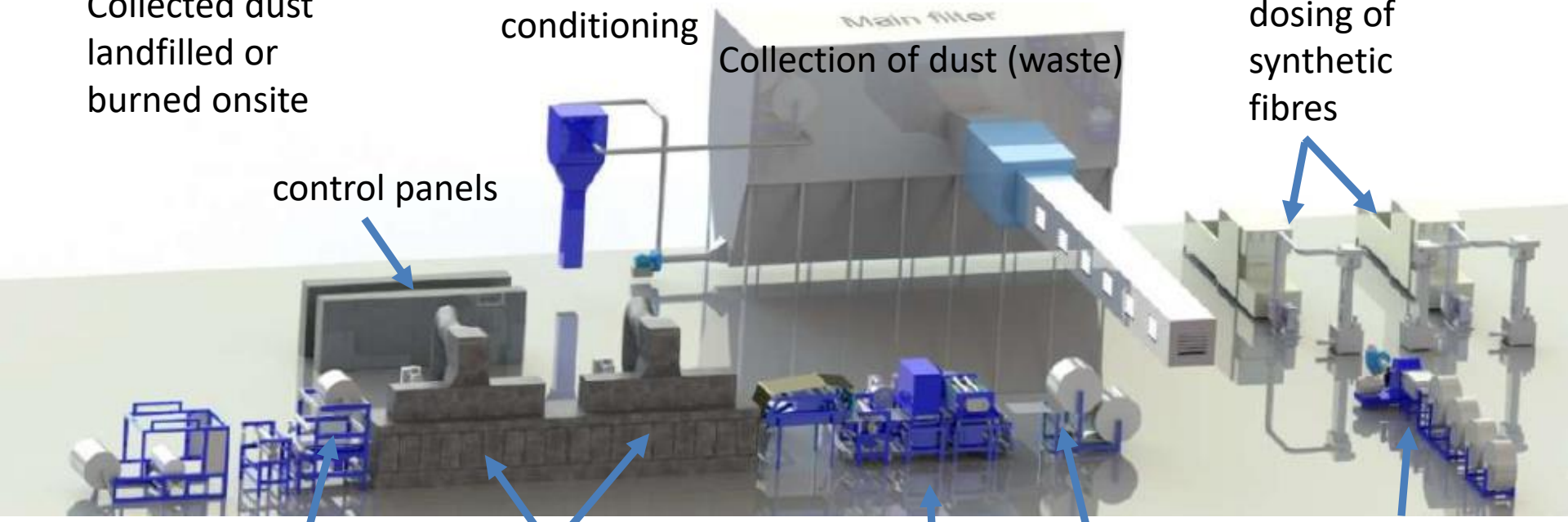

Gentle defibration with
hammermill w.o. fiber cutting

Airlaying and
Thermoforming at 160 °C

# Short fiber airlaid technology

- Nonwovens Airlaid machines:
  - From 1000 – 25 000 t/a at 1000 – 3000 mm width

Supported by Dan-Web®



# DryThermoforming

- Hammer Mill Technology
  - Energy Saving
  - High Throughput
  - Low maintenance
  - High degree of defibration

} Low operating costs

Fixed beater rotor

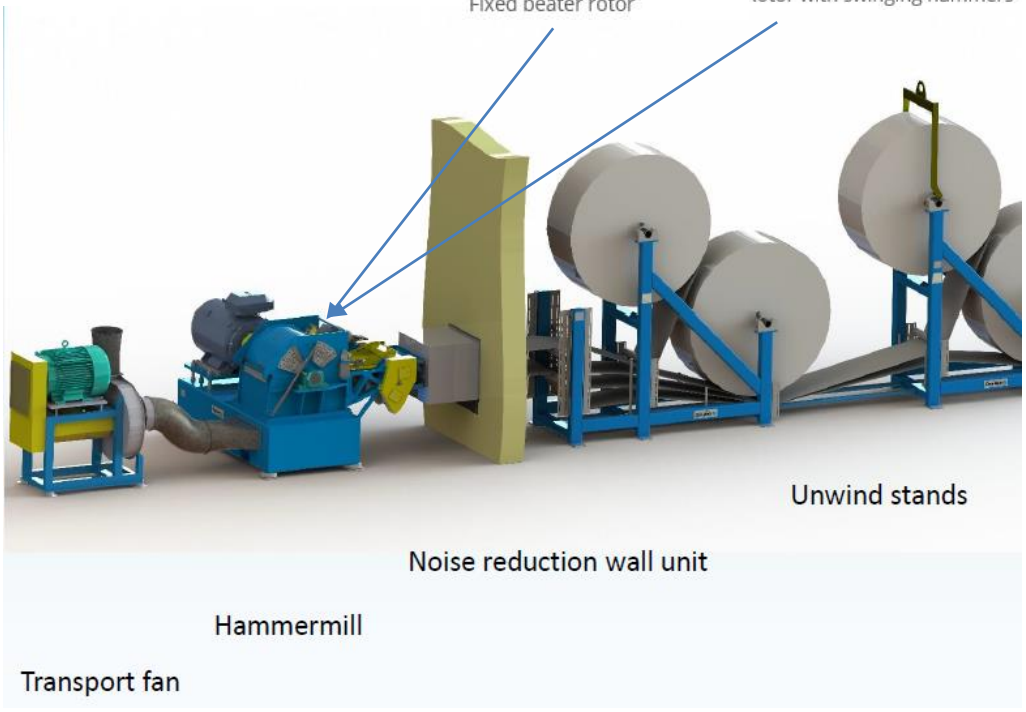
Rotor with swinging hammers

Degree of defibration:

Knits/knots

Fines (<0,2 mm)

Good Fluff



# DryThermoforming

## Hammer mill may cut fibers and introduce kinks

- Affects the hight of the formed shredded pulp pad and the deep drawability in the hot press

Before hammer milling

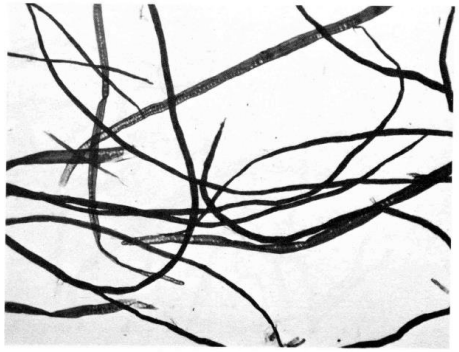


Figure 7a. Southern pine kraft, sheet pulp, not fluffed (X50).

Figure 8a. Western hemlock sulfite, sheet pulp, not fluffed (X50).

after hammer milling

Figure 7b. Southern pine kraft, fluffed (X50).

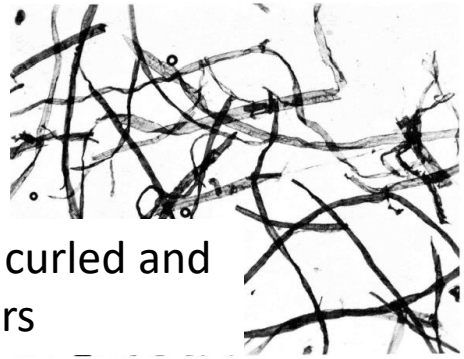


Figure 8b. Western hemlock sulfite, fluffed (X50).

A bit more curled and kinked fibers

The fluffiness of the pulp is affected by the single fiber stiffness (aspect ration and the fiber wall thickness) and the conditions in the hammer mill (fines, curled/kinked fibers)



*J.E: Tostevin and G.R. Quimby INDA Technical Symposium Nonwoven Product Quality in Miami Florida 1975; pp. 48 - 66

# DryThermoforming

## Process

- 99,9 % material utilisation – press waste is backwarded to hammermills
- Significantly less energy compared to wet pulp mould, but higher raw material cost with fluff pulp and tissue/laminate
- Modular equipment
- Compared to plastic: 90 % CO2 footprint than  and similar product cost




https://www.pulpac.com/

# DryThermoforming

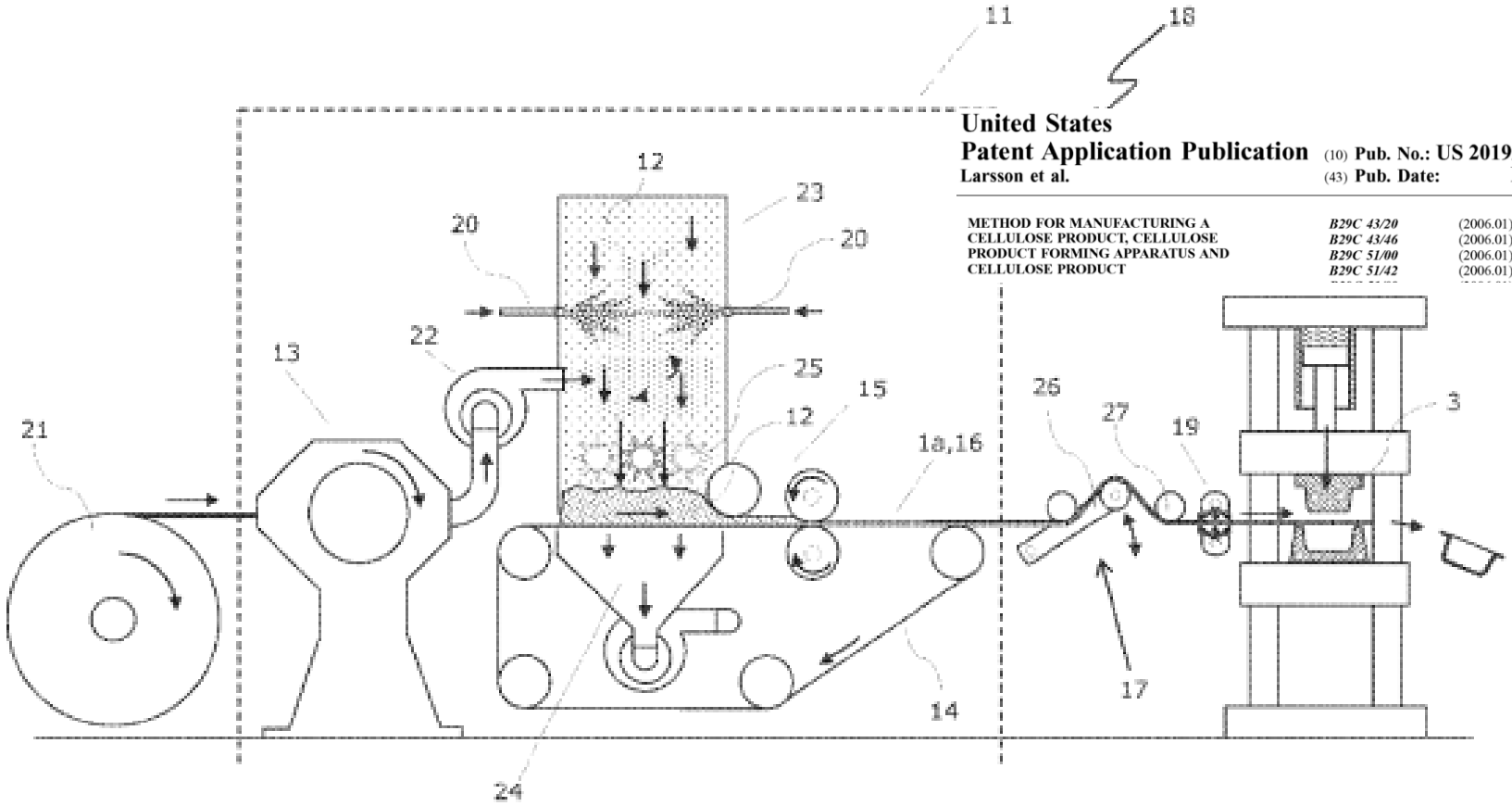
## Process

- Production of fluffed fibers
  - Fluff pulp and hammer mill
- Forming a fiber batt
  - Onto a vacuum belt
- Fiber modification
  - Wax emulsion
- Surface finishing
  - Laminating of films
- Hot-Pressmoulding
  - At 100 – 200 °C (typically 150 – 170 °C), up to 100 MPa
- Links
  - Video or Video with details


https://www.pulpac.com/

# DryThermoforming

## Core process represents PulPac‘s sold units on market




United States
Patent Application Publication (10) Pub. No.: US 2019/0070819 A1
Larsson et al. (43) Pub. Date: Mar. 7, 2019

METHOD FOR MANUFACTURING A CELLULOSE PRODUCT, CELLULOSE PRODUCT FORMING APPARATUS AND CELLULOSE PRODUCT

| | |
|---|---|
| *B29C 43/20* | (2006.01) |
| *B29C 43/46* | (2006.01) |
| *B29C 51/00* | (2006.01) |
| *B29C 51/42* | (2006.01) |

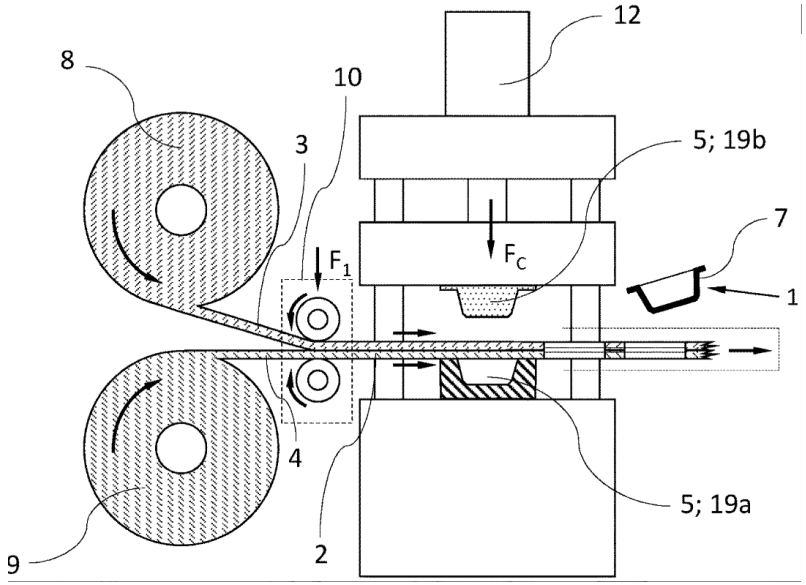


https://www.pulpac.com/

# DryThermoforming

## Patents secure technology around the globe

- 26 patent families
- 84 granted national patents
- Up to two new patents per month



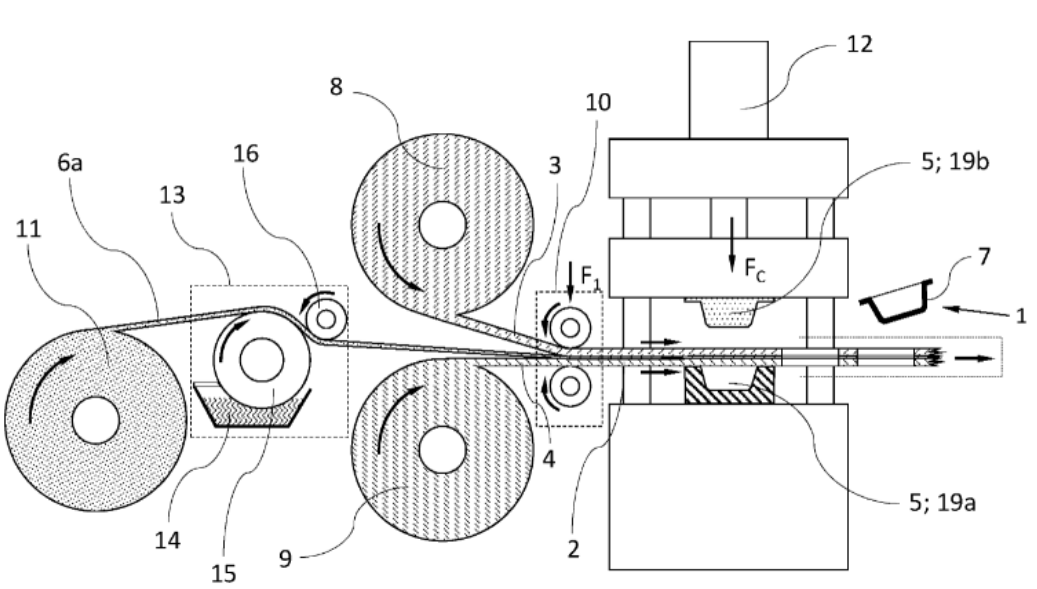




Fig. 2

# DryThermoforming

## Patents secure technology around the globe

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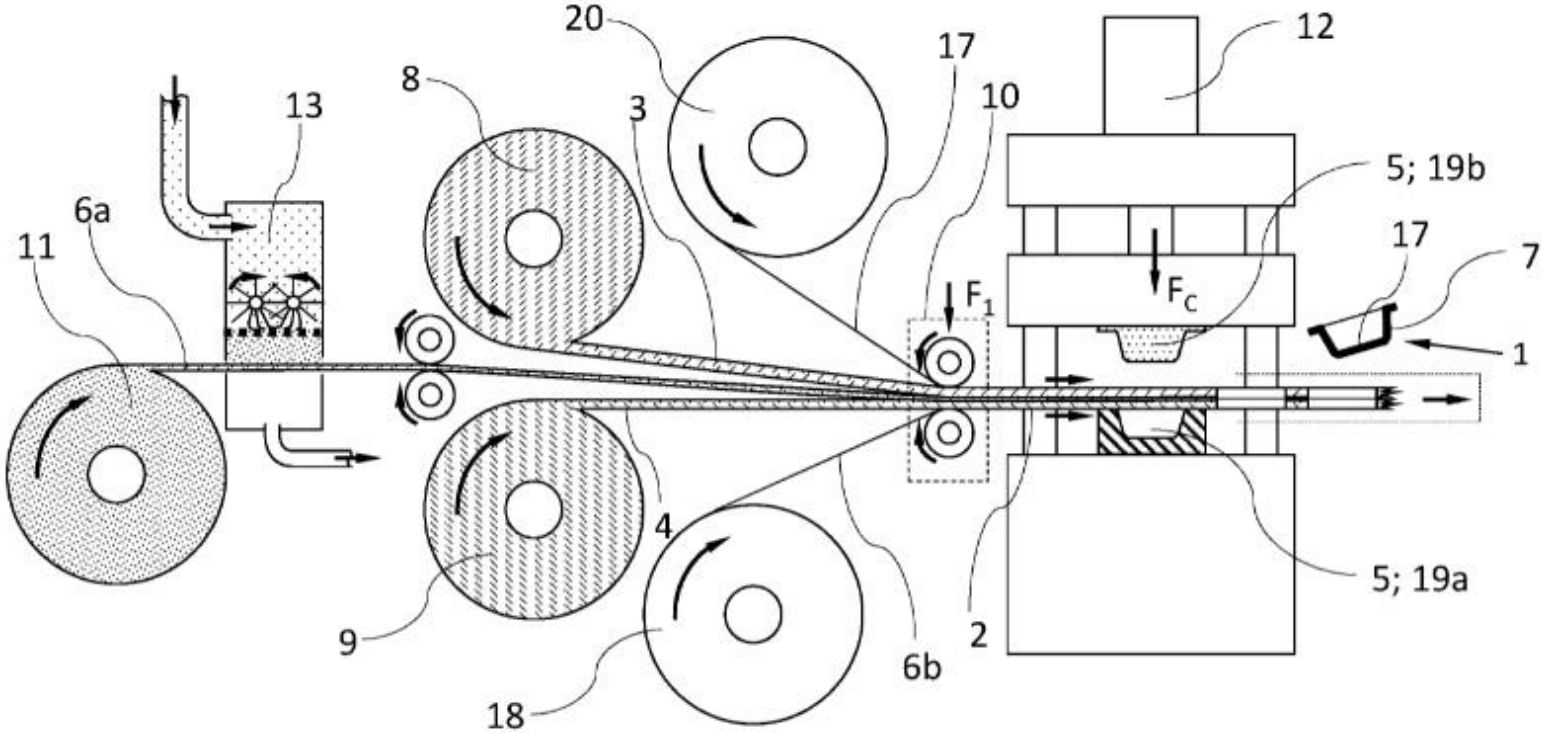


# DryThermoforming

## Patents secure technology around the globe

Latest idea: peelable film in trys ensures full barrier (depending on material of the film)

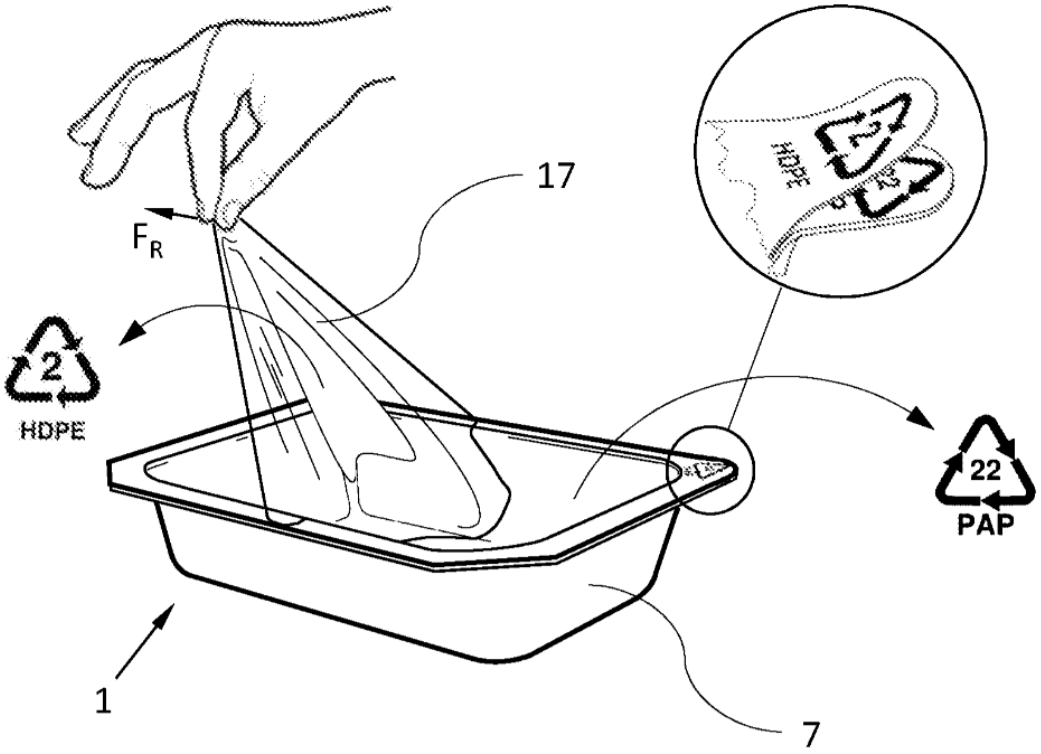
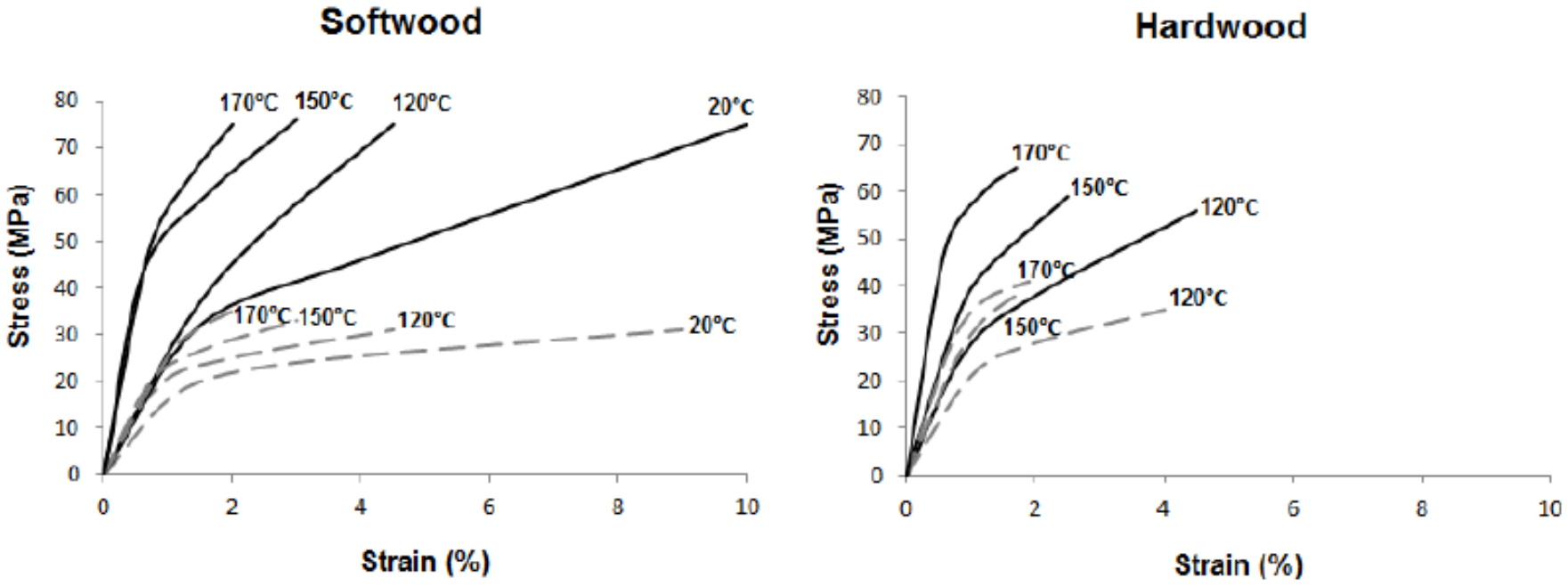



Fig. 5

# DryThermoforming

## Effect of hot-pressing of cellulose

hot pressing of beaten (solid) and non-beaten kraft pulp (dashed) resulted in density of 1,3 g/cm³




Pronounce increase in stiffness at lower ductility at same tensile



Halonen 2012 Structural changes during cellulose composite processing

# DryThermoforming

**Effect of hot-pressing of cellulose**

increased stiffness at same tensile strength

Tensile strength:

macroscopic factors affect the tensile strength

Tensile stiffness and ductility:

explained by improved fiber-fiber bonding

actual bonding mechanism not yet fully understood:

interfibril fusion bond (mechanical interlinking)



Halonen 2012 Structural changes during cellulose composite processing

# DryThermoforming

## Effect of raw materials on hot-pressing,:

**Table 3.** Mechanical properties of the compression-moulded pulps at 170°C (data with standard deviation in parentheses).

| | **Young's modulus** (GPa) | **Ultimate tensile strength** (MPa) | **Strain to failure** (%) |
|---|---|---|---|
| Kraft paper-grade pulp | 6.3 (3.0) | 109 (7.2) | 6.3 (1.4) |
| *Sulphite pulps:* | | | |
| Dissolving-grade | 11.5 (2.4) | 75.1 (4.5) | 2.0 (0.1) |
| Paper-grade | 12.0 (2.1) | 74.0 (3.4) | 2.4 (0.3) |



Halonen 2012 Structural changes during cellulose composite processing

# DryThermoforming

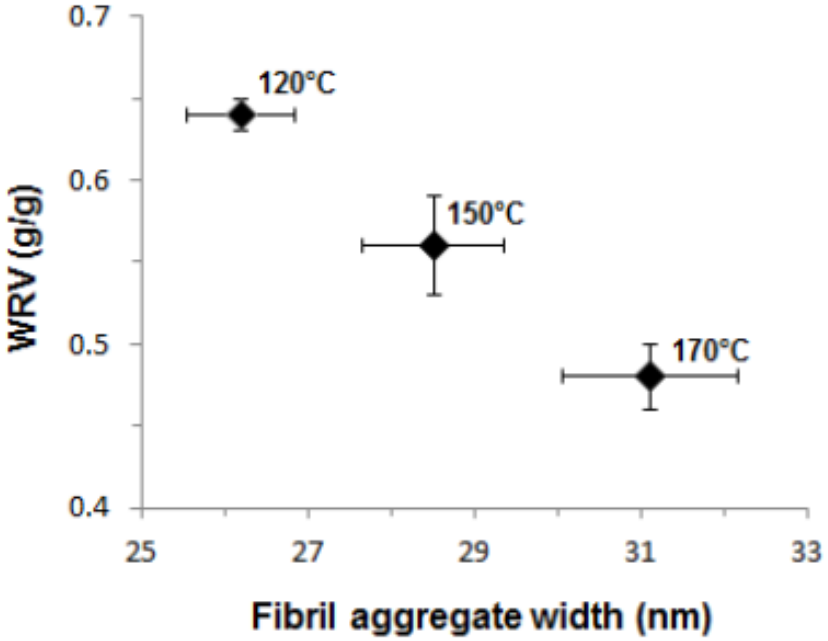
## Positive influence on swelling

Sulfite paper pulp and dissolving grade pulp tend to be more aggregated fibril structure than kraft pulp after wet pressing

Kraft paper pulp: 0,9 g/ g water

Sulfit paper pulp: 0,5 g/g water

Sulfite dissolving: <0,5 g/g water




Dissolving pulp



Halonen 2012 Structural changes during cellulose composite processing

# DryThermoforming

## Summary

- New technologies will challenge the old fashioned WetThermoforming for food contact applications (bowls, cuttleries, cup lids,..) where direct food contact is required (no low quality recycled pulp).
- Dry Thermoforming still relies on expensive fluff pulp (more expensive than paper pulps), but PulPac seeks for new technologies that allow them to use flash dried pulps …. So far this technology has not been found!

- If you want to join me find this technology, please contact me Leitner.Johannes_PhD@gmx.at

# Outlook

## My offerings

- Interdisciplinary seminars and technology development support for universities and international public funded projects

- Extended lecture related to the state of the art in textile recycling technologies

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# Thank you for your attention