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THE FABULOUS DESTINIES OF SPENT GRAIN

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BREWERIES

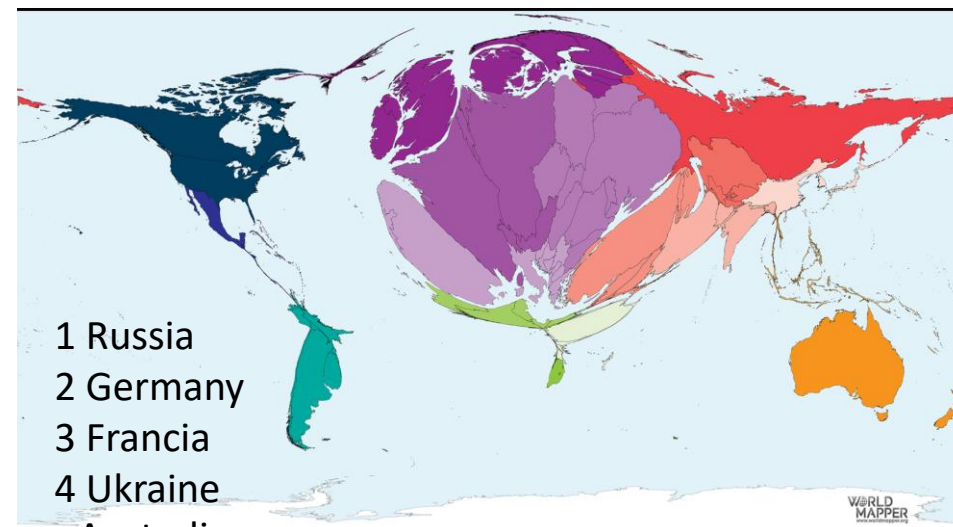
After work, beer is the favorite drink of Europeans and Americans!

- 32 billion L of beer produced in E** in 2023 !
- Barley is to beer what grapes are to wine!
- First materials: H₂O, barley, hops and yeast
 - Drinkable H₂O is abundant (for the moment...)
 - Barley is the 4th most important cereal crop in the world



3.4 million tons of spent grain waste/year

Barley production into the world in 2016



- 1 Russia
 - 2 Germany
 - 3 Francia
 - 4 Ukraine
- Australia
Canada
Spain
Turkey
United Kingdom
USA

BREWERY WASTE

A logistical and environmental challenge

Breweries produce a surprising amount of waste !

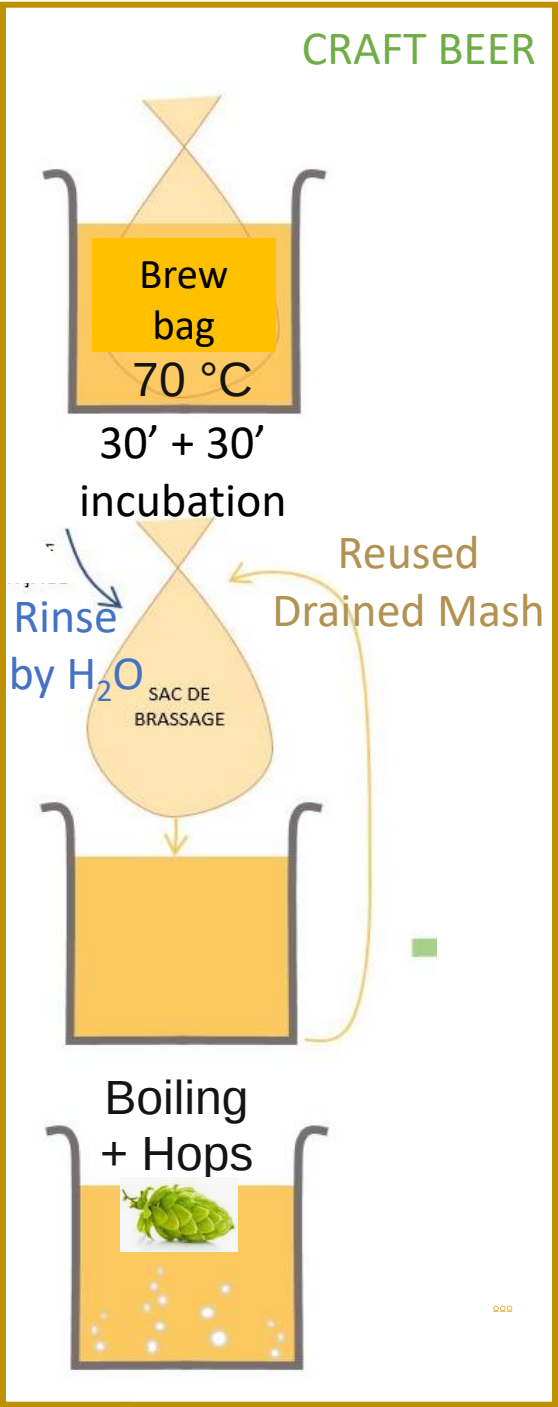
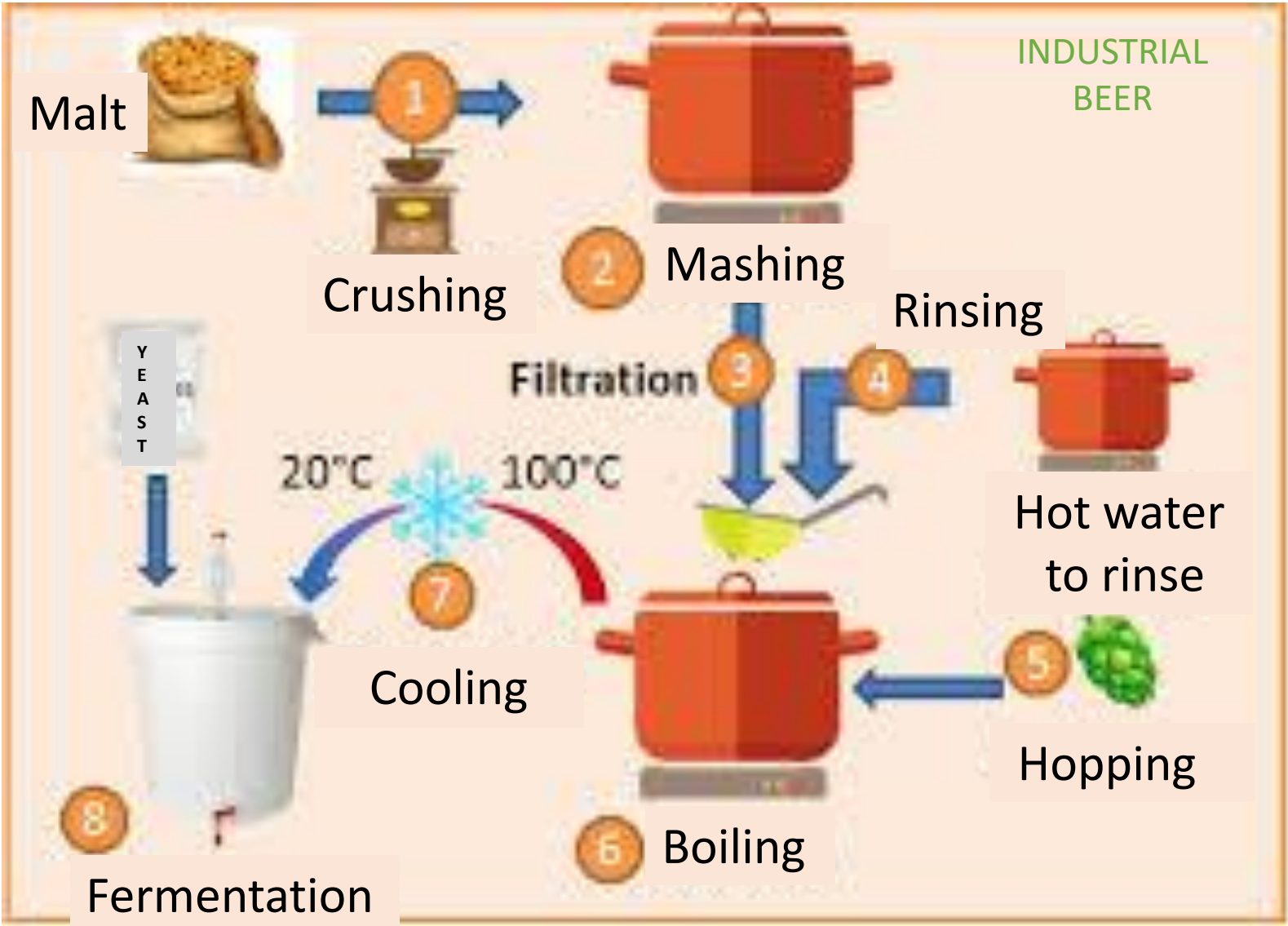


6-8 l H₂O to make 1 l of beer!



=6 million tons of biowaste

HOW IS BEER MADE?



BEER WASTE IS PRODUCED IN AMAZING QUANTITY

Spent hops: 800-1.2 kg of hops waste/100 L of beer produced

Residual Yeast: 1.5-3 kg of waste/ 100 L of beer produced

Wastewater: 600-800 L of H₂O/ 100 L of beer produced
Brewery **wastewater** has a **high sugar content**



Brew Spent grain (BSG): 100 L of beer = 20 kg of spent grain = are **85% of all by-products**
Main waste product from the beer brewing process!

In the past: it was just dumped in landfills!!!

Currently: 20% waste is thrown away and buried (= pollution and greenhouse gas production!)

But, it can be easily recycled or repurposed!

And since 01/2016, if an industry produces > 1 ton/year of biowaste, they have to be upcycled

How is it recycled or repurposed?

70% OF SPENT GRAIN IS GIVEN TO FARMERS AS FOOD FOR LIVESTOCK

- ✓ For centuries , spent grain is given by craft beer producers to farmers as food
- ✓ it is **one of the best animal feed!**
- ✓ Best suited for **Cattle, sheep, goats, pigs.**
- ✓ Less for **poultry** unless dried and further processed
- ✓ Easy to transport (if brewery is near farm)
- ✓ But, **the transfer time** must be < **6 hours** from the brewery to the farm!



Nutrient	Approximate Dry Basis
PROTEIN	20-30 %
FIBER	40-70%
FAT	5-10%
MOISTURE(WET)	85%

✓ Highly nutritious!



SPENT GRAIN COMPOSTING

- ✓ Effective
- ✓ Low-cost
- ✓ Circular economy especially for small to mid-size breweries



Ideal C:N ratio for composting: **25–30:1**

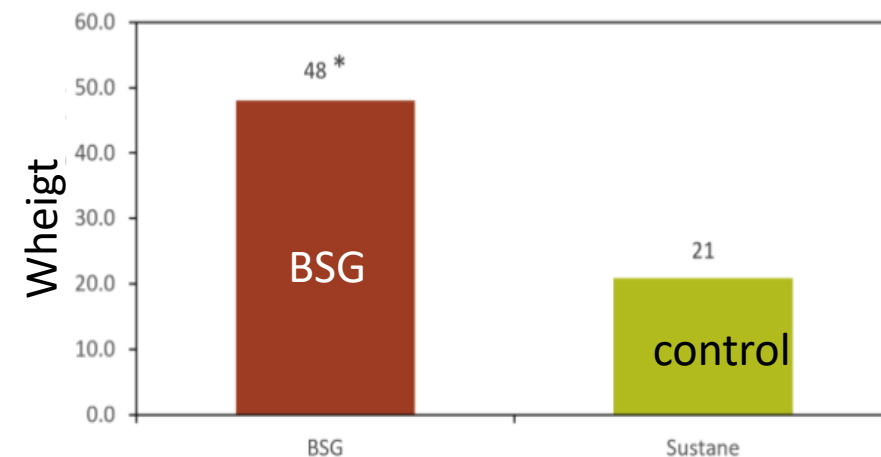
- **1 part spent grain (C:N = 12–15:1)**
(too much N on its own!)
- **2–3 parts C-rich browns**

New easy method 2023:
Spent Grain directly as a
**Soil Amendment for
Eggplant**

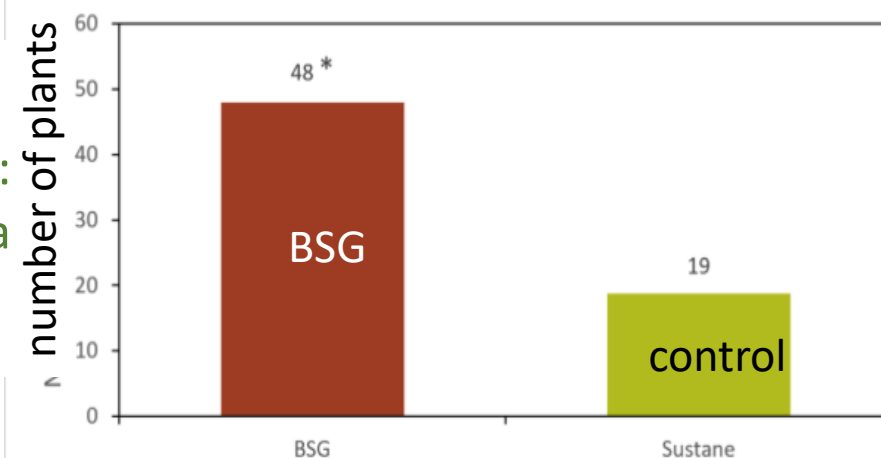


PRACTICAL FARMERS OF IOWA
COOPERATORS' PROGRAM Farmer-Led Research

BSG more than doubled weight of marketable eggplant compared to Sustane



BSG more than doubled number of marketable eggplant compared to Sustane



SPENT GRAIN, A GROWING MEDIUM FOR MUSHROOM FARMS

- Spent grains, like coffee grounds, can be used as a growing medium for mushroom cultivation
- But aerated substrate is essential (60%)
- But spent grain has **12-15 times more N than C**
- Ideally: a mixture of 1/3 spent grains, 1/3 coffee grounds, and 1/3 straw for aeration, no compaction and contamination
- + sterilized in an oven (60 to 80°C, 2 h) beforehand to avoid
 - **strong fermentation odors**
 - **to decrease sugar content**



Mushroom farming



- Gray oyster mushroom
- Golden oyster mushroom
- Yellow oyster mushroom
- Pink oyster mushroom
- Indian oyster mushroom
- « champignon de Paris » / Button mushroom

10% OF SPENT GRAIN IS USED TO MAKE BIOGAS

- **Biogas Production:** - O₂ digestion to produce CH₄
- ↑ demand for energy in Eu**!
- No need for fossil fuels !
- Circular economy



Low cost fuel

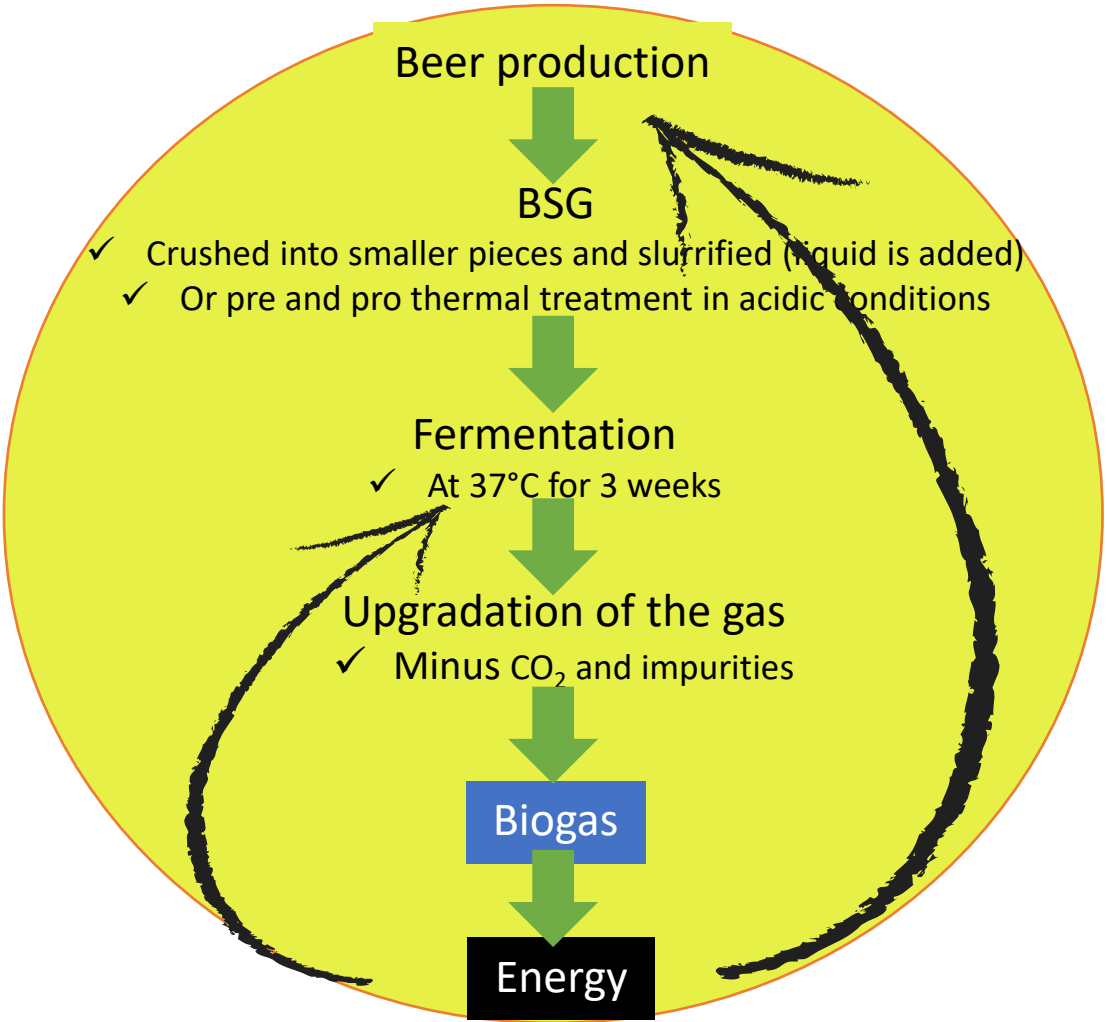


But large scale production
not yet possible!

Microorganism



-O₂, 37°C, 3 weeks



BIOCHAR FROM SPENT GRAIN

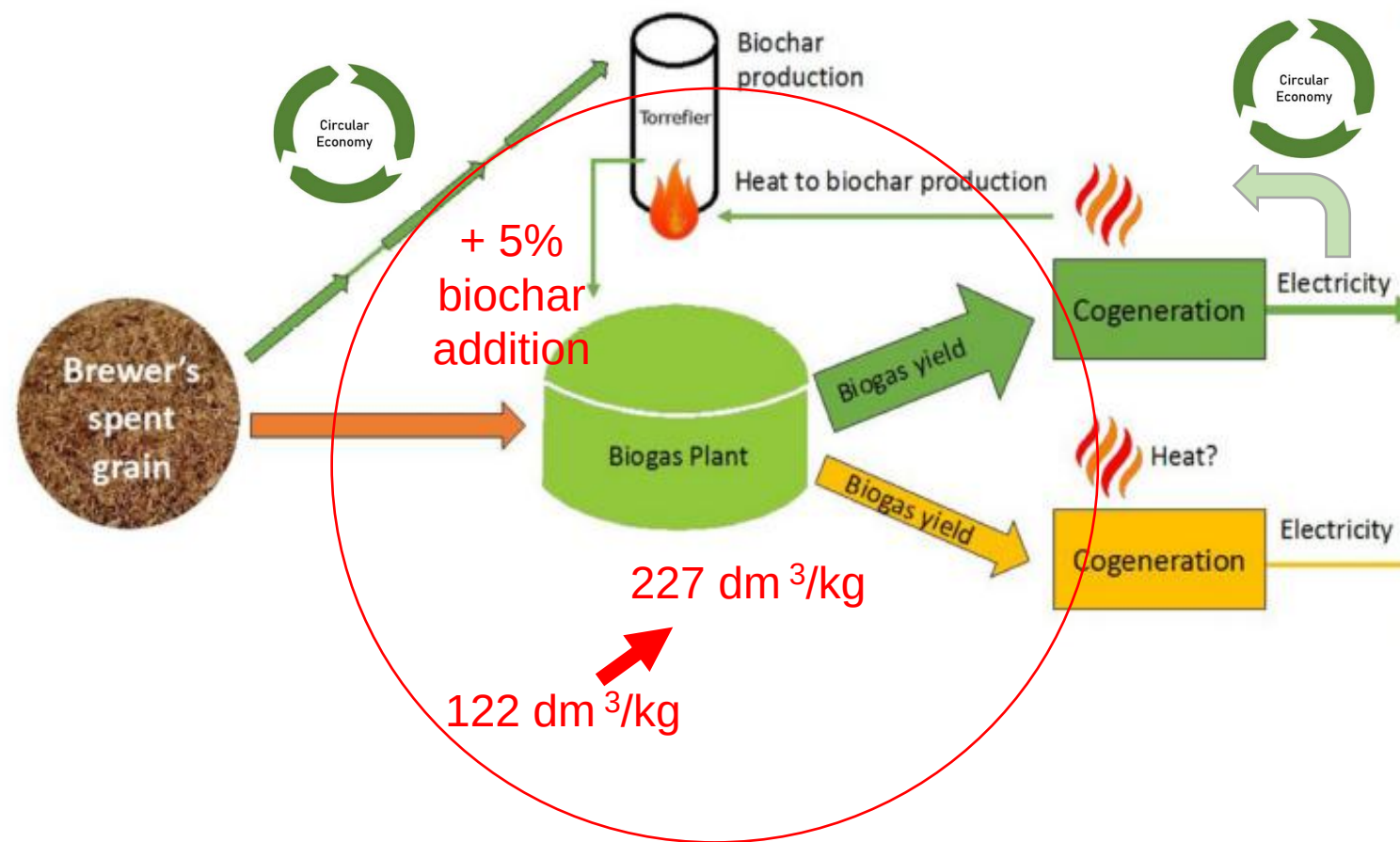
- How, by **pyrolysis** of spent grain to make soil-enhancing **biochar** (= Agrichar)
- Or used to ↑ **soil quality**
- Or used to **decontaminate** soils or sediments (**adsorbant** properties)
- **Against global warming** as a solution for **long-term capture of atmospheric C in soils**



- ✓ Low T°C pyrolysis suitable for agricultural uses
- ✓ Higher T°C pyrolysis enhances its porosity
- ↑ contaminant absorption



SPENT GRAIN BIOCHAR INCREASES BIOGAS PRODUCTION YIELD



Synergistic combination of BSG torrefaction and anaerobic digestion to increase the biogas production yield by up to 227 dm³/kg!

SPENT GRAIN FEED FORMATS & PROCESSING OPTIONS

➤ Wet Feed (Fresh)

- Simplest option
- Used it **within 2–3 days**
- Can be **given directly to nearby farms**
- Preservation Tip: Store in **sealed containers or silos**

➤ Silage

- For fermented spent grain
- Often mixed with corn or grass
- **Extended shelf life (to months)**
- Requires - O₂ storage conditions

➤ Pelletized dry feed

- Requires energy to dry (**oven or rotary dryer**).
- **Long shelf life** (easier to store and ship)
- Can be milled into flour or granules
- Mixed with molasses, vitamins, or other ingredients
- Easy to handle, transport, and portion
- Need energy, but **creates a commercial product!**



Quality & Safety Considerations:

- **Avoid mold growth** (mycotoxins):
 - Always keep dry or use quickly!
- **Metal & plastic contamination:**
 - Filter before distribution!
- **Salt or cleaning agents:**
 - To Ensure no brewery chemicals are present in the mash

SPENT GRAIN FLOUR: A FUNCTIONAL INGREDIENT FOR FOOD APPLICATIONS



↑ **upcycled spent grain into food products** due to

- ✓ Nutrient contents
- ✓ Flavor and color contents



Add 10% to 20% in the flour mixture (wheat)

- ✓ **Clean and minimally processed ingredient**
- ✓ **Nutritional, Technical, Economic and Marketing advantages**
- ✓ **Reduces the environmental impact and cost of recipes**
- ✓ Reduces gluten content

Nutrient	Approximate Dry Basis
PROTEIN	20-30 %
FIBER	40-70%
FAT	5-10%
MOISTURE(WET	85%
POLYPHENOL	
MINERAL (Ca/P/Mn/ Zn)	



Increases H₂O absorption ability



Then, decreases the volume of the bread



Blond
Spent Grain
Flour

Amber
Spent Grain
Flour

Brown
Spent Grain
Flour



SPENT GRAIN IN COOKIES AND CRACKERS

Adding 12-20% spent grain to the cookie formulation:

- 👍 increases the proportional fiber and protein content =
- 👍 promising for groups of consumers with nutritional deficiencies

Home-made:

«Recy cookie» from our « Innovative Food Product » (our Master’s degree AMU in 2022)



10% almonds
25% dried apricots

16% butter
12% sugar
10% eggs

12% wheat meal
12% spent grain meal

Industrial:



Salt
Brewer’s
Crackers



Sugar Bars
and cookies

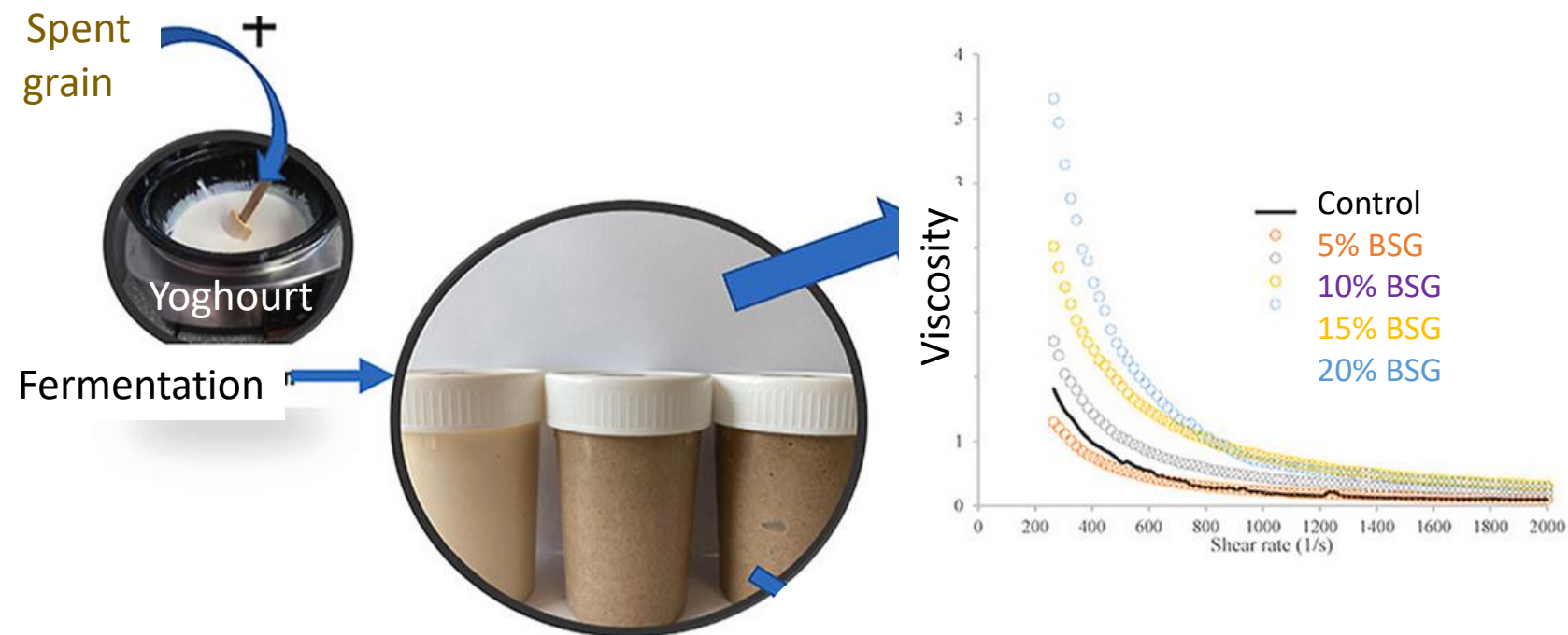


SPENT GRAIN IN PASTA PRODUCTS

- ✓ Higher macronutrient contents like protein, fiber and glucan
- ✓ Good sensory quality
- ✓ Accelerates H₂O penetration
- ✓ Reduced cooking time
- ✓ No major influence on functional properties, even at concentrations of 20%!



HIGH-FIBER-CONTENT BSG REGULATES THE FOOD MATRIX BEHAVIOR OF YOGHURT



Substituting 5%–10% BSG improved yoghurt quality :

- ✓ Acidity
- ✓ Lactic acid bacteria growth
- ✓ Rheological behavior

1. Dried and powdered spent grain of various particle sizes for exfoliating soap
2. Spent grain wax (from malt extraction using supercritical CO₂)
 - Contains some unsaturated fatty acids able to moisturize the skin

+

- Healthy by its nutritive composition:

- ✓ High in dietary fiber
- ✓ Protein rich with essential AA (lys, glu, cys, met)
- ✓ Phenolic antioxidants (ferulic, p-coumaric, caffeic acids)

- A filter that reduces the absorption of sugar into the blood!



« The more fiber you eat at the start of your meal, the slower your sugar absorption will be! »

DESIGN AND ECO-CONCEPTION OF BIOMATERIALS FROM SPRENT GRAIN

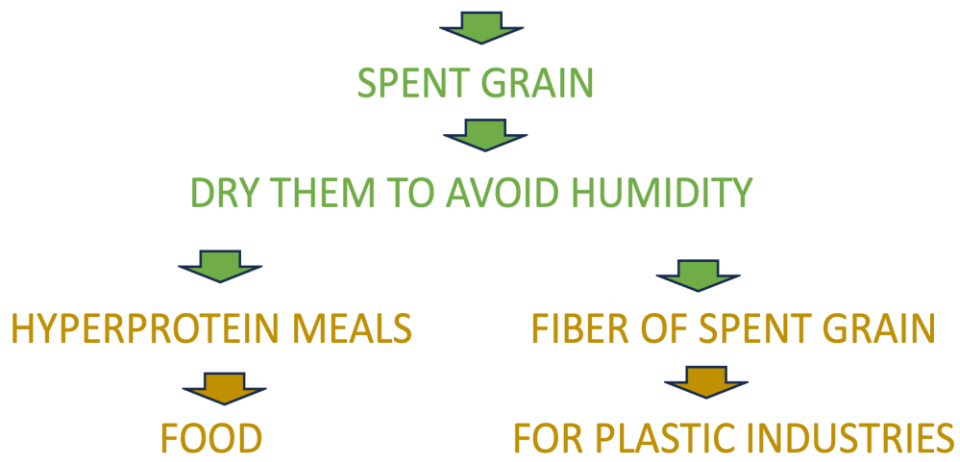
- ✓ Economical, ecological and innovative furniture
- ✓ Materials with excellent technical characteristics:
 - Flexibility
 - Resistance
 - Malleability
 - waterproofin



WAKE ME UP!



CRAFT BEWERIE FROM SOUTH-EAST OF FRANCE



Glass Stool Coasters Acoustic panels and bricks

SPENT GRAIN CLOTHES

Japanese brewery Sapporo turns brewing waste into jeans



- ✓ Sapporo Breweries Ltd., one of Japan's major brewers
- ✓ Collaboration with Shima Denim Works: clothing from bagasse (sugarcane waste)
- ✓ Spent grain is first transformed into washi (a traditional Japanese paper)
- ✓ which is used to spin and weave the future denim
- ✓ 300€/pair of jeans
- ✓ But production too low!

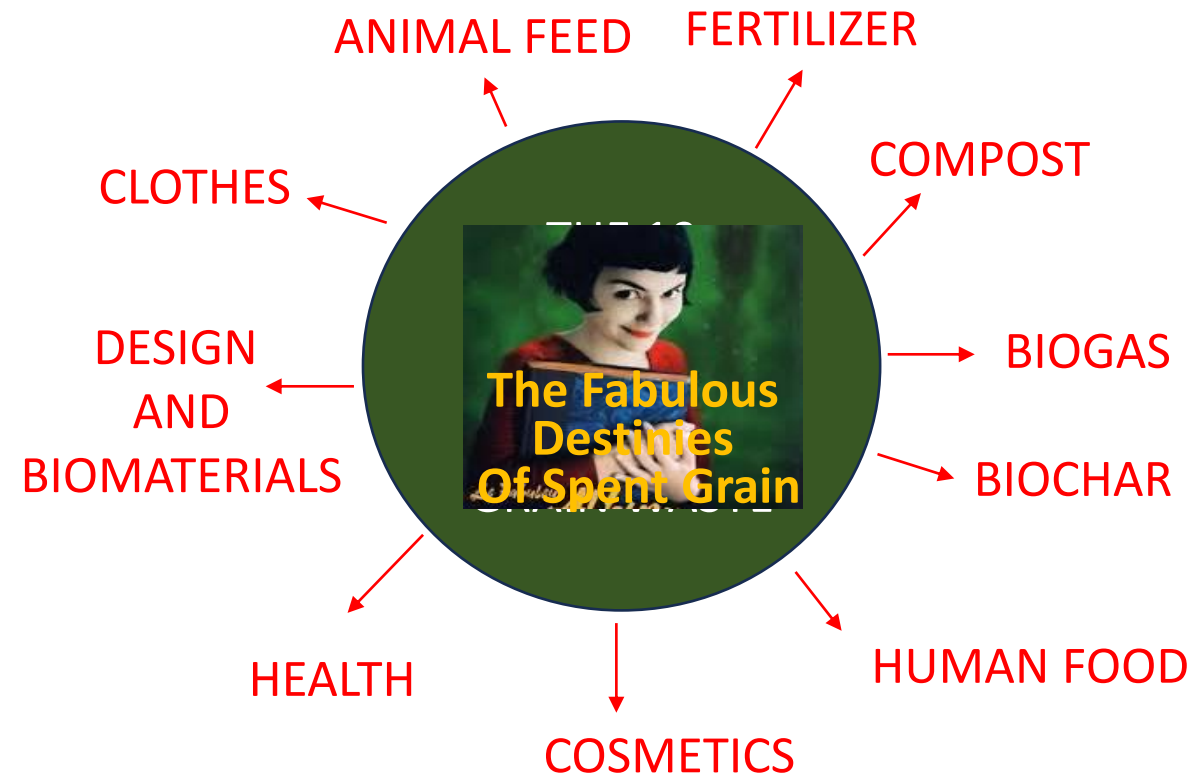


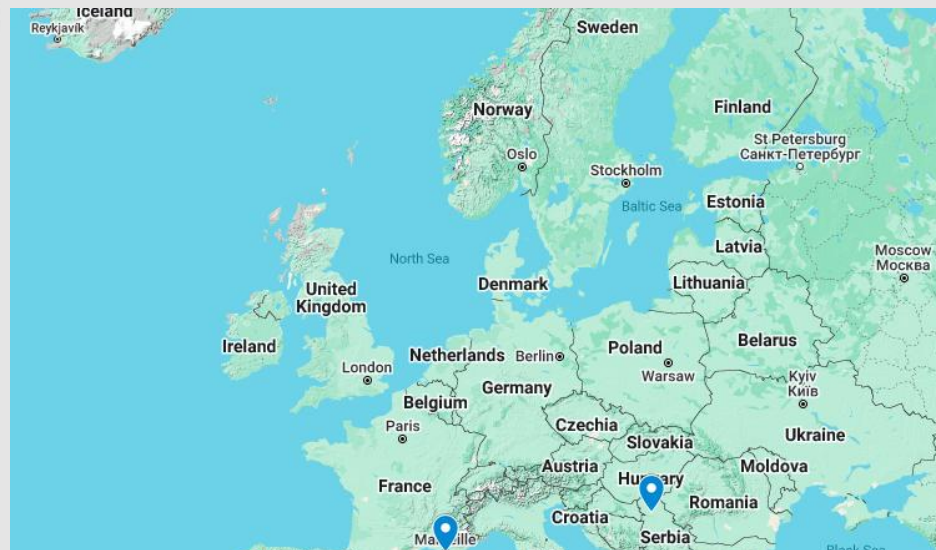
Bottom line:
How to Increase jean production?
Drink more beer!



THE FABULOUS DESTINIES OF SPENT GRAIN

« The reuse of spent grain brings both economic and environmental benefits, thus reducing pollution »





Thank you for your attention!

