Rheological characteristics of filamentous cultivation broths and suitable model systems

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Background and motivation

Aim: Rheological characterization of biological systems and establishment of a database for the rheological modeling of these cultivation broths for any possible use in the field of fluid dynamics and (bio)process engineering.

- Filamentous microorganisms show a diverse morphology (e.g. freely dispersed mycelia, dense pellets).
- Rheology influences mixing and mass transport → impact on overall performance of cultivation process.
- Studied filamentous microorganisms: a) fungus *Aspergillus niger*, bacteria b) *Lechavalieria aerocolonigenes,* and c) *Actinomadura namibiensis.*
- Model Fluids facilitate experimental research (e.g. fluid dynamic examinations).
- Non-biological model fluids compared with flow behavior of examined filamentous microorganisms.

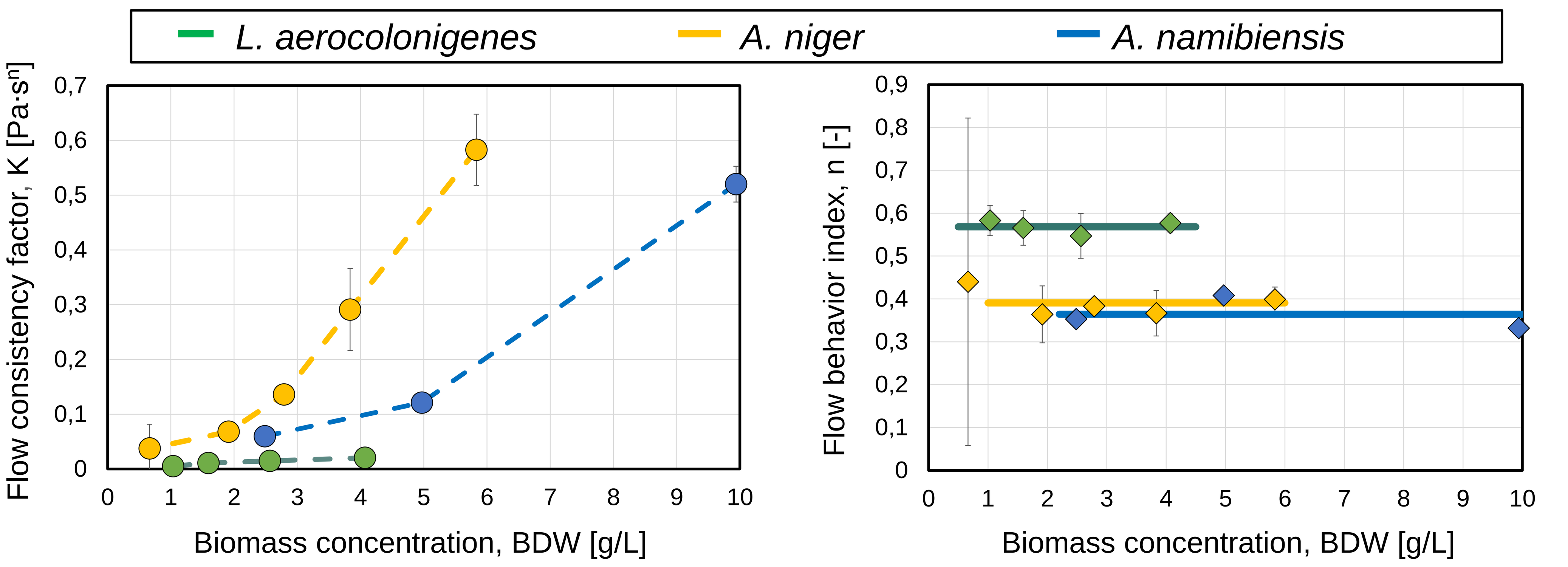
Measurement systems

- Biomass-containing samples: rotational rheometer Malvern, Kinexus lab+ with vane
- Model fluids: rotational rheometer Anton Paar, MCR 302 with cone-plate system
- Curve fitting according to the Ostwald–de Waele power law: $\tau = K \cdot \dot{\gamma}^n$

The applied vane tool.

Destroyed mycelia of *A. niger* due to shear forces in the plate-plate system using a gap of 1.5 mm and a shear rate up to 500 s⁻¹. The use of cone/plate-test systems generally led to destroyed or agglomerated mycelia.

Influence of the biomass concentration on rheological parameters



When filamentous morphology = const.:
- K = *f* (BDW); ↑ BDW ➡ ↑ K

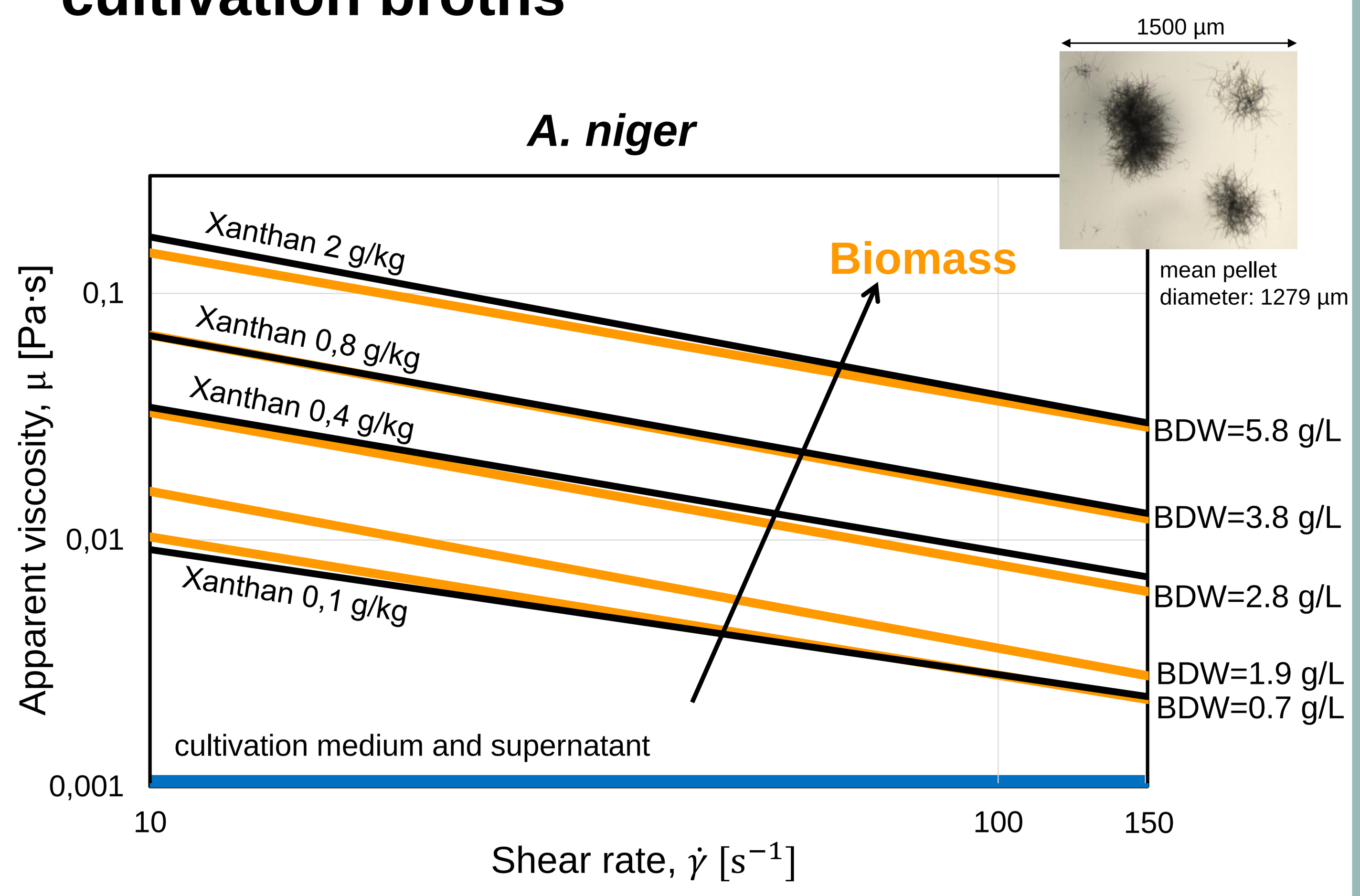
When filamentous morphology = const.:
- n ≠ *f* (BDW)

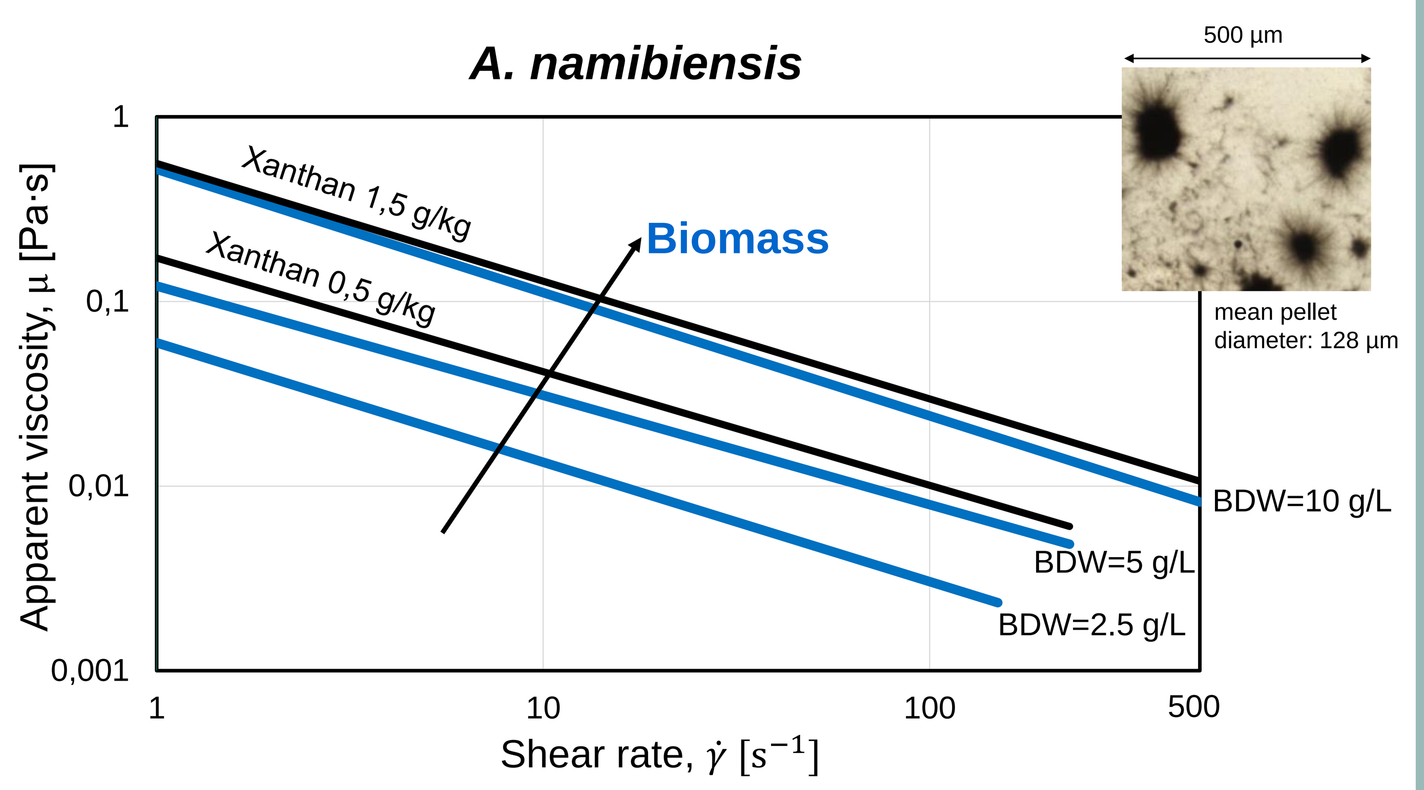
Non-biological model fluids

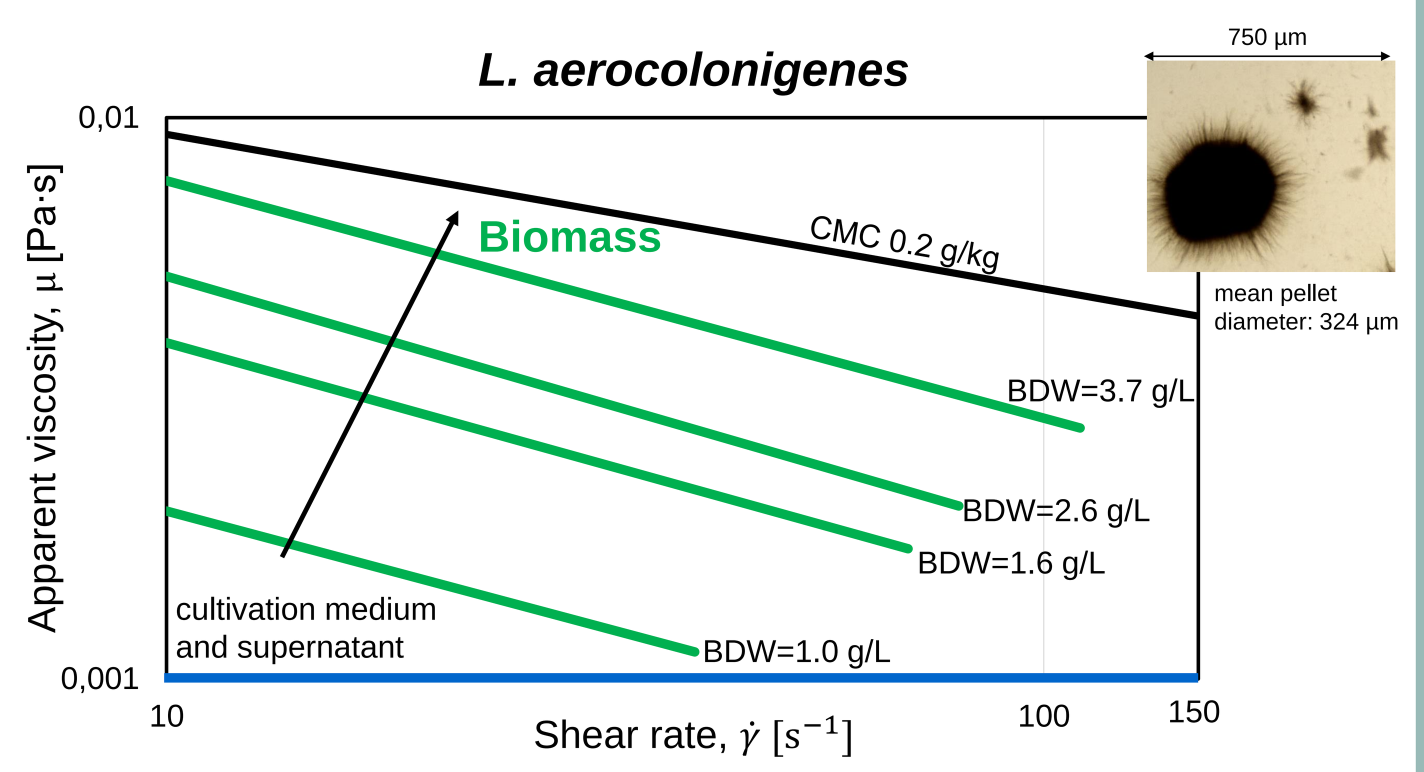
- μ [Pa·s] = *f* (X [g/kg]) ; K [Pa·s^n] = *f* (X [g/kg]) ; n [-] = *f* (X [g/kg])

Model system	Rheological behavior	Range of concentration X	Rheological model	Modeled range of shear rates $\dot{\gamma}$
Glycerol	newtonian	10-1000 g/kg	$\mu=0.0006 \cdot e^{0.0064 \cdot X}$	1-1000 s^{-1}
Invert sugar sirup		10-1000 g/kg	$\mu=0.0005 \cdot e^{0.0056 \cdot X}$	1-1000 s^{-1}
Polyvinylpyrrolidone (Luviskol ® BASF)		10-200 g/kg	$\mu=0.0033 \cdot e^{0.0337 \cdot X}$	1-1000 s^{-1}
Polyethylenglycol (PEO/PEG)	shear thinning	20-300 g/kg	Ostwald-de Waele power law $K=5 \cdot 10^{-7} \cdot X^{2.93}$, $n=0.9632 \cdot e^{-0.003 \cdot X}$	100-1000 s^{-1}
Carboxylmethyl cellulose (CMC)		0.1-10 g/kg	Ostwald-de Waele power law $K=0.1144 \cdot X^{1.2105}$, $n=0.7417 \cdot e^{-0.05 \cdot X}$	10-1000 s^{-1}
Xanthan gum solution		0.5-10 g/kg	Ostwald-de Waele power law $K=0.3591 \cdot X^{1.09}$, $n=0.3707 \cdot X^{-0.124}$	1-1000 s^{-1}

Rheological modeling of filamentous cultivation broths







Conclusions and further challenges

- Vane (impeller) **measuring system** preferable for mycelial biomass, but fails for low and high shear rates due to sedimentation and turbulence effects, respectively.
- Increased viscosity of cultivations broths results from presence of microorganisms.
- Flow consistency factor K increases with **biomass concentration**, flow behavior index n is independent of biomass.
- Xanthan most suitable **model fluid** for *A. niger* and *A. namibiensis.* Low viscous shear thinning behavior of *L. aerocolonigenes* not sucessfully modeled yet.
- Newtonian cultivation broths consisting mainly of pellets and rheological elastic characteristics of the examined systems not part of the investigation so far.

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