



Alginate based bio-adhesive for bookbinding application

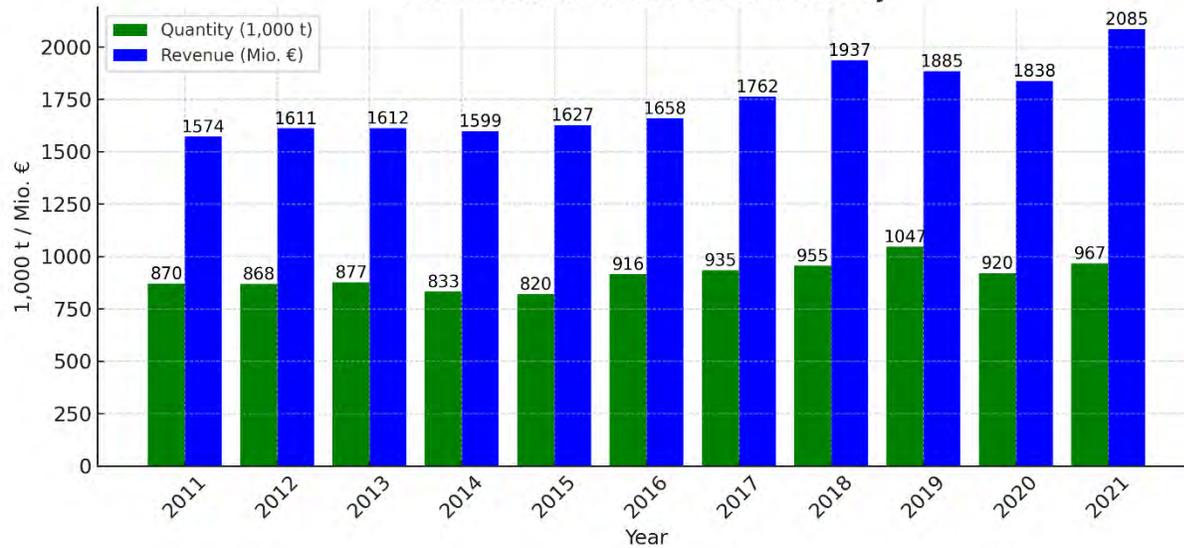
Lukas Jenner

Situation

Adhesive production in Germany in 2021:

- 967.000 t (all applications)
 - 31.000 t paper industry
 - 6.500 t book binding

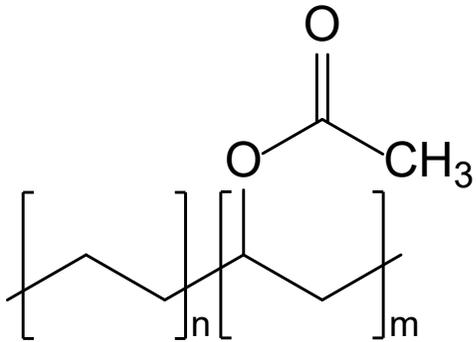
Production of Adhesives in Germany



	Share of production in %	2020	2021	2022	2023
Manufacturing industry	100	-9,6	-4,3	2,9	3,8
Transport	18,1	-21,1	-4,3	3,0	4,8
Food, beverages and tobacco	10,1	-2,4	-0,7	0,3	3,1
Paper (incl. printing)	3,2	-6,3	4,1	3,3	3,4
Metals and metal products	12,4	-11,2	7,8	3,2	2,4
Machinery and equipment	14,5	-11,7	8,7	3,7	4,6
Electronic, Electrical & Optical Equipment	6,2	-5,7	10,3	5,0	4,3
Chemistry	8,5	-0,5	5,5	2,4	3,0
Wood (without furniture)	1,4	6,1	-1,8	0,6	3,0

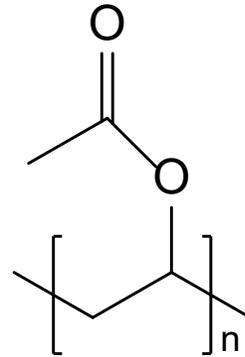
Situation

- Petrochemical adhesives are dominating in bookbinding
- EVA, PVAc, PUR
- Excellent adhesive properties
- Cost effective



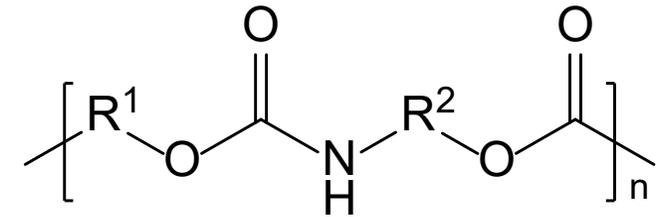
EVA

Hotmelt



PVAc

Dispersion



PUR

Reactive
Hotmelt

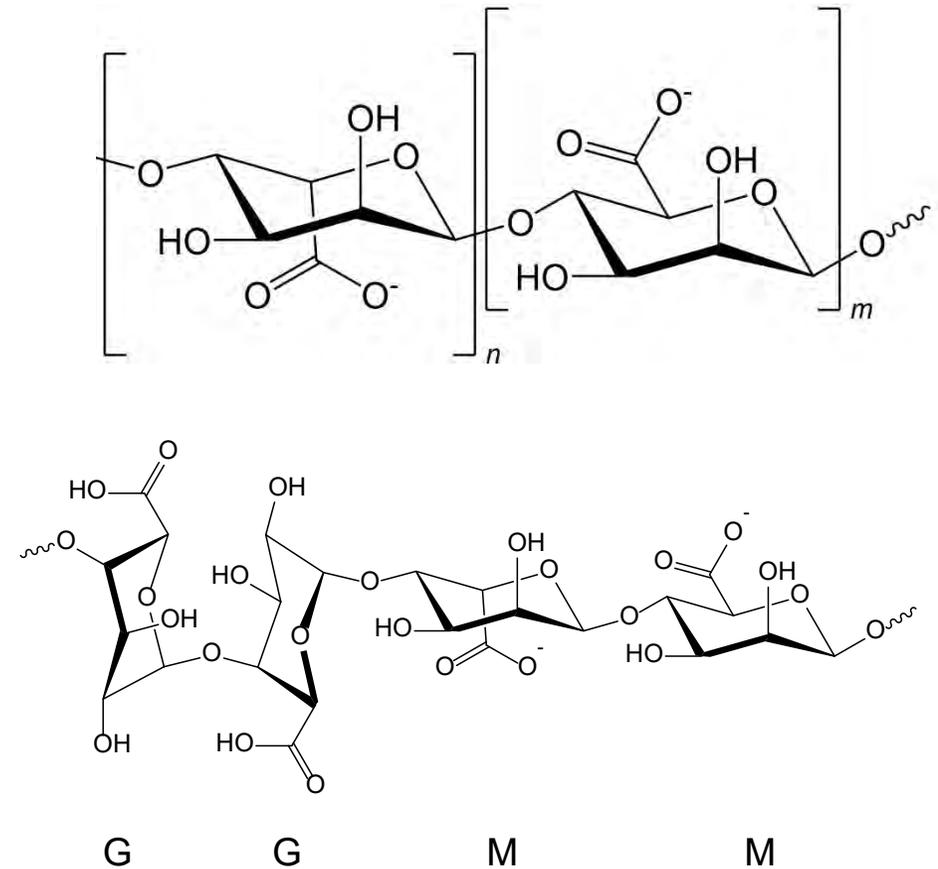
Problems

- Synthetic adhesives are not readily biodegradable
 - Micro plastic in the environment
 - Huge environmental problems
- Oil is a finite raw material
- Problems in the recycling process
 - Detachment of adhesive particles leads to increased water consumption in the flotation process
 - Problems in the reactivating of wood fibres
 - “Stickies”

Alginate

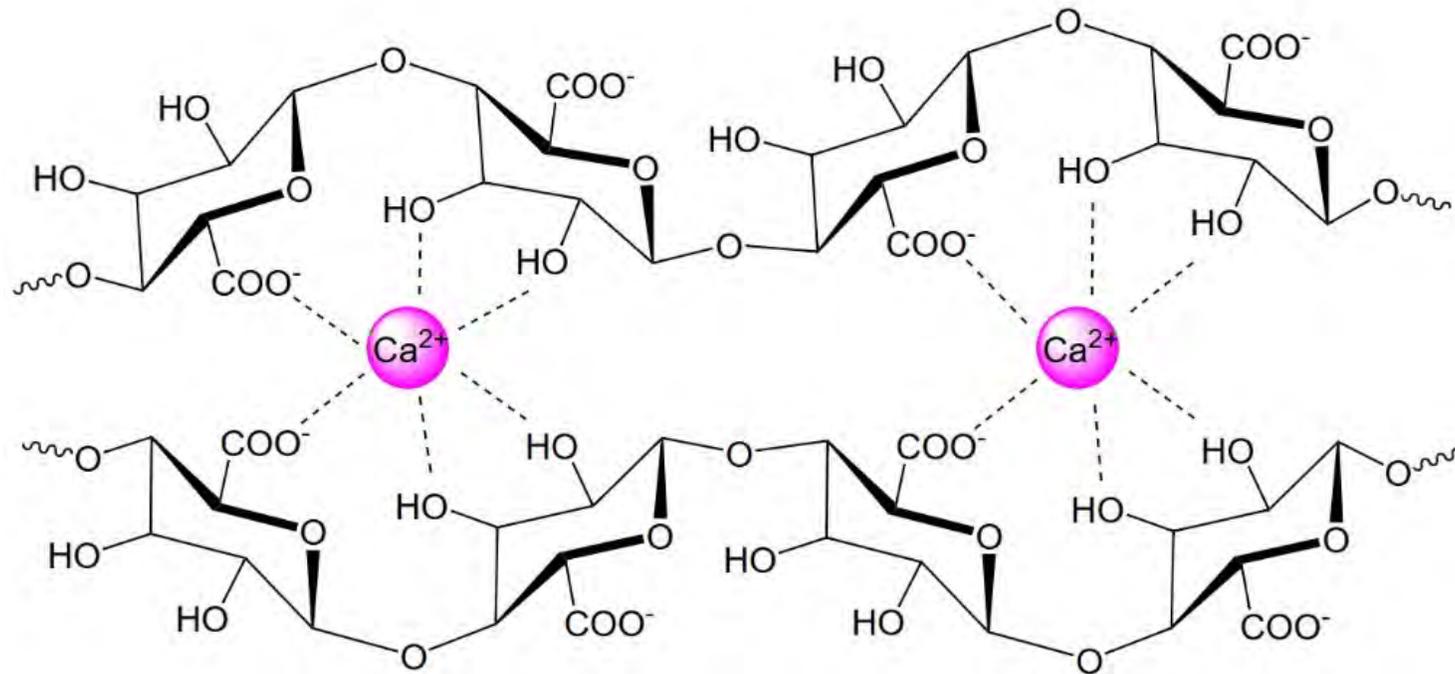
Alginate gels

- Alginate is produced from brown algae
- Global demand for alginate is estimated at 26 million tons per year



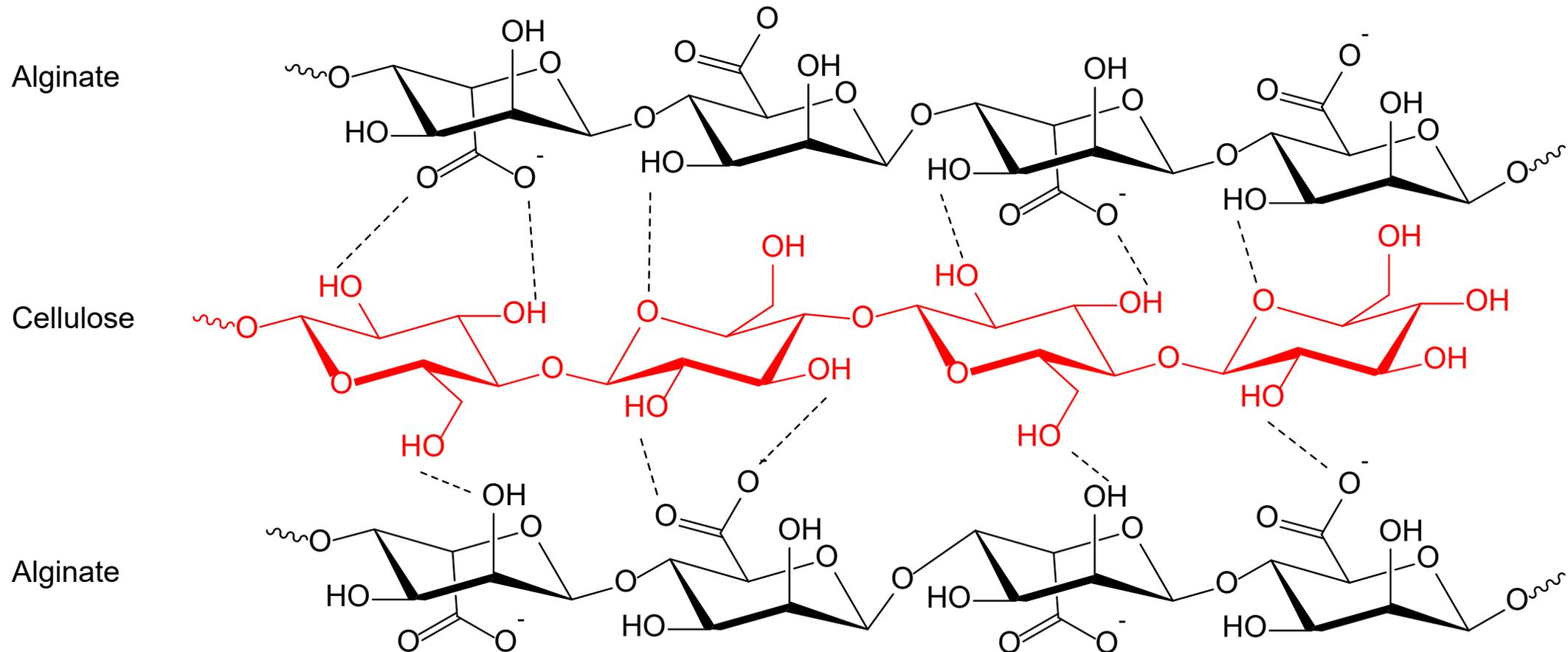
Alginate with calcium ions

- Cross-linking via Ca^{2+} → stable and irreversible gel
- Egg box model
- Ionic interactions
- Possible with other divalent and trivalent cations (Ba^{2+} , Al^{3+} , Fe^{3+} ,



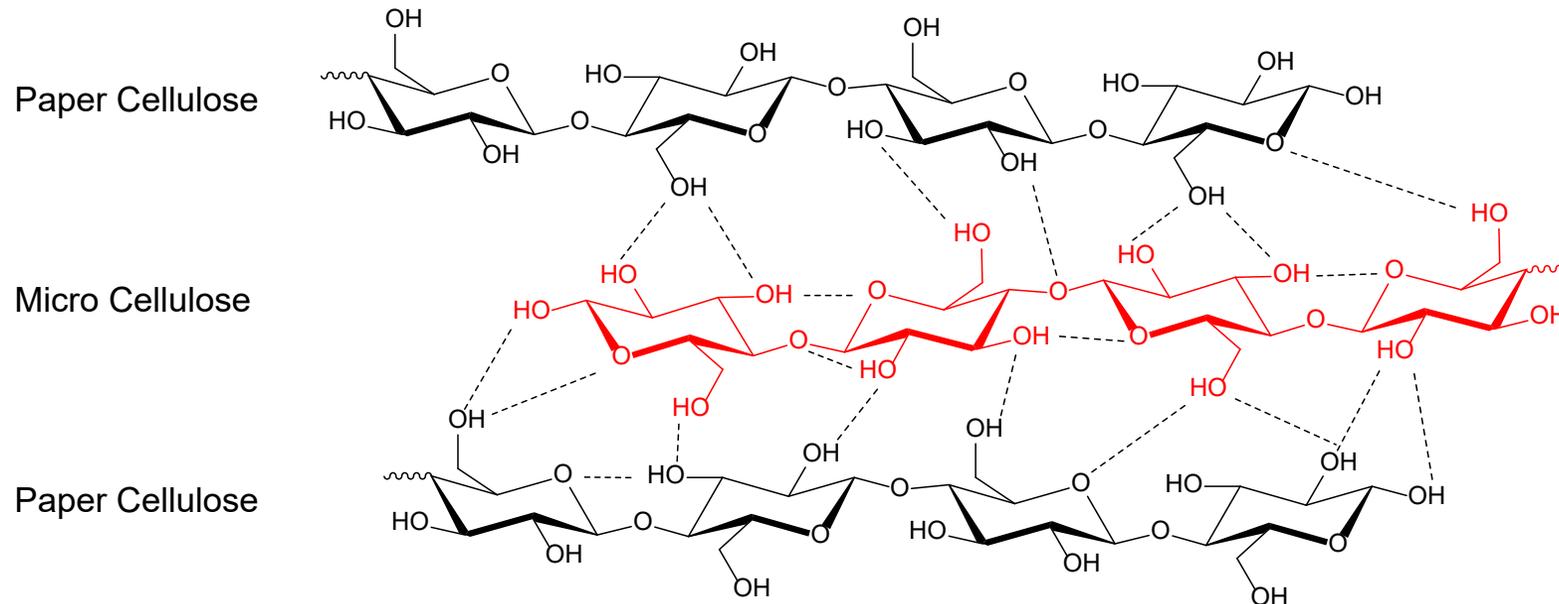
Adding Cellulose

- Adding cellulose → building hydrogen bridges
- Improves tensile strength

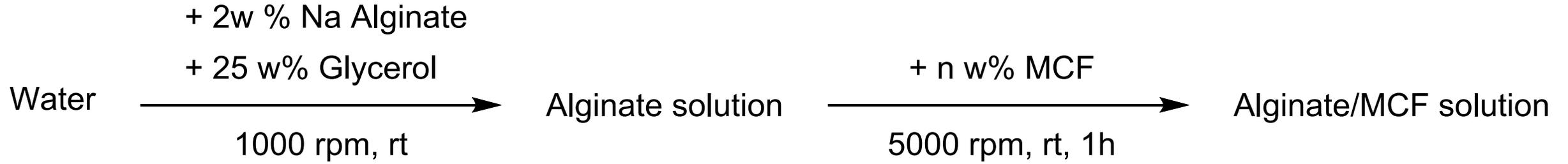


Idea

- Specific adhesion
 - Alginate interacts via polar forces
 - Micro/Nano Cellulose interacts via hydrogen bonds
- Mechanical adhesion
 - Micro/Nano Cellulose penetrates paper



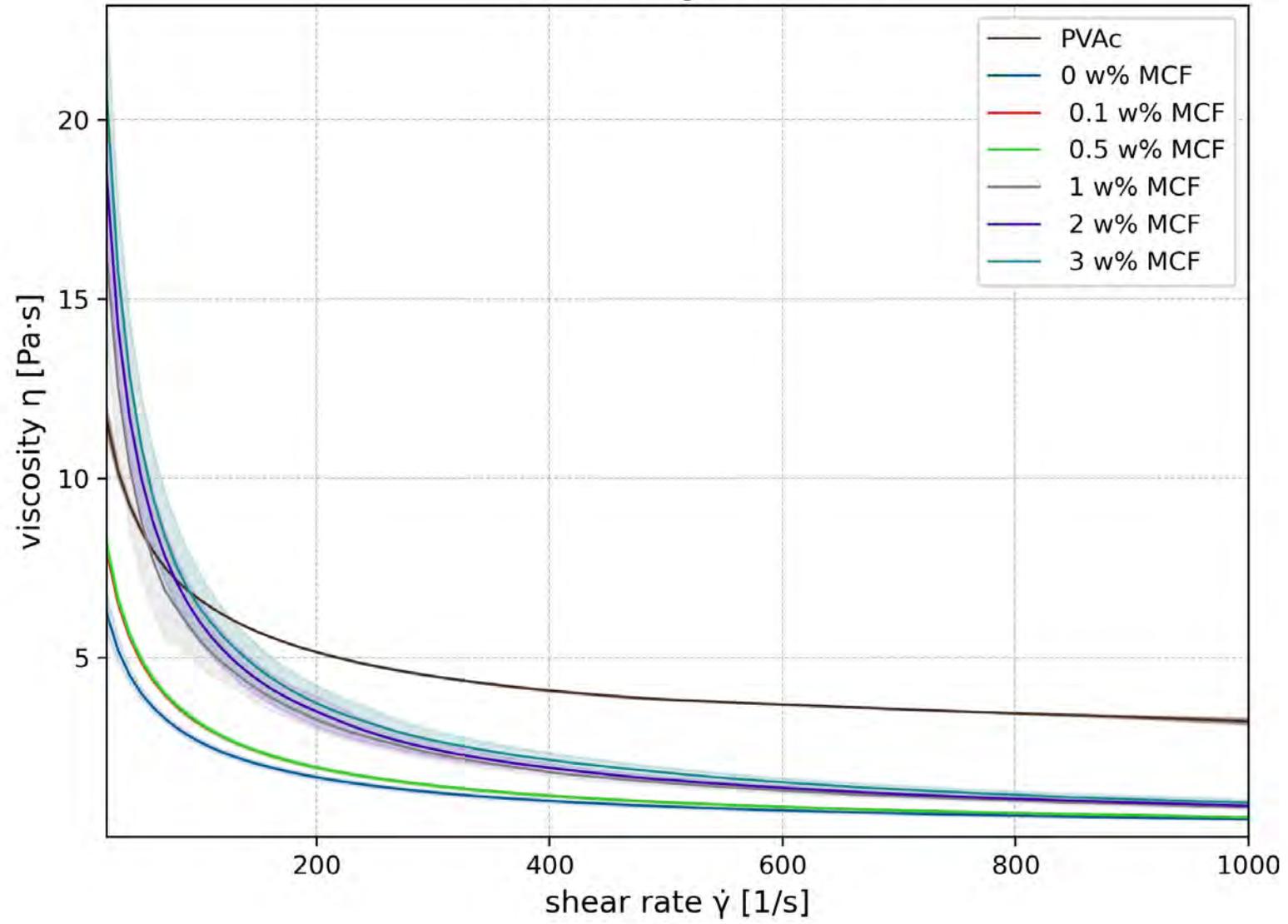
Alginate adhesive



MCF (micro cellulose fibre): size 20 μm



Viscosity curve

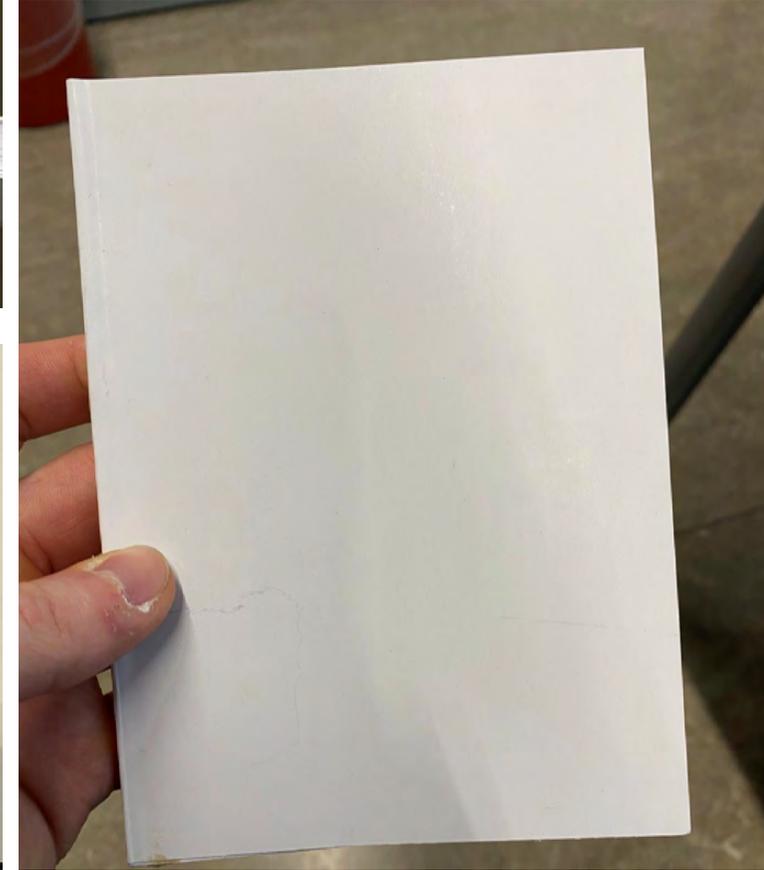
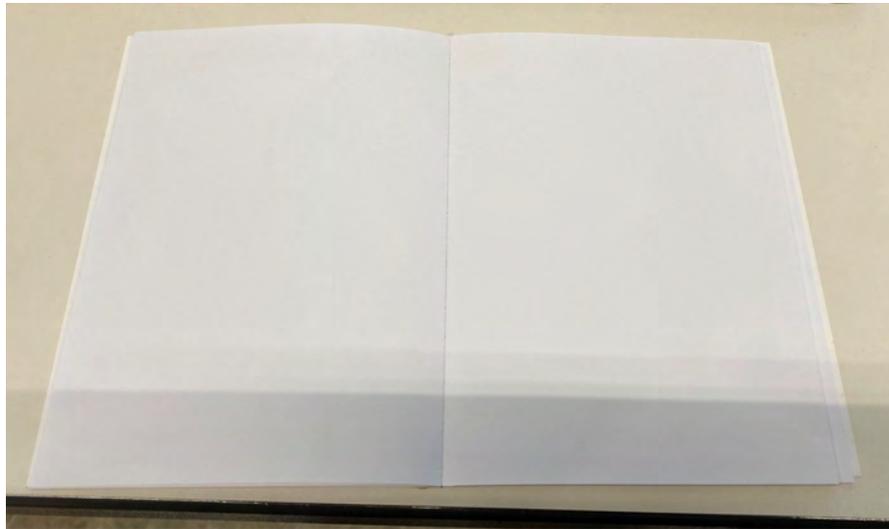


Binding test books



Binding test books

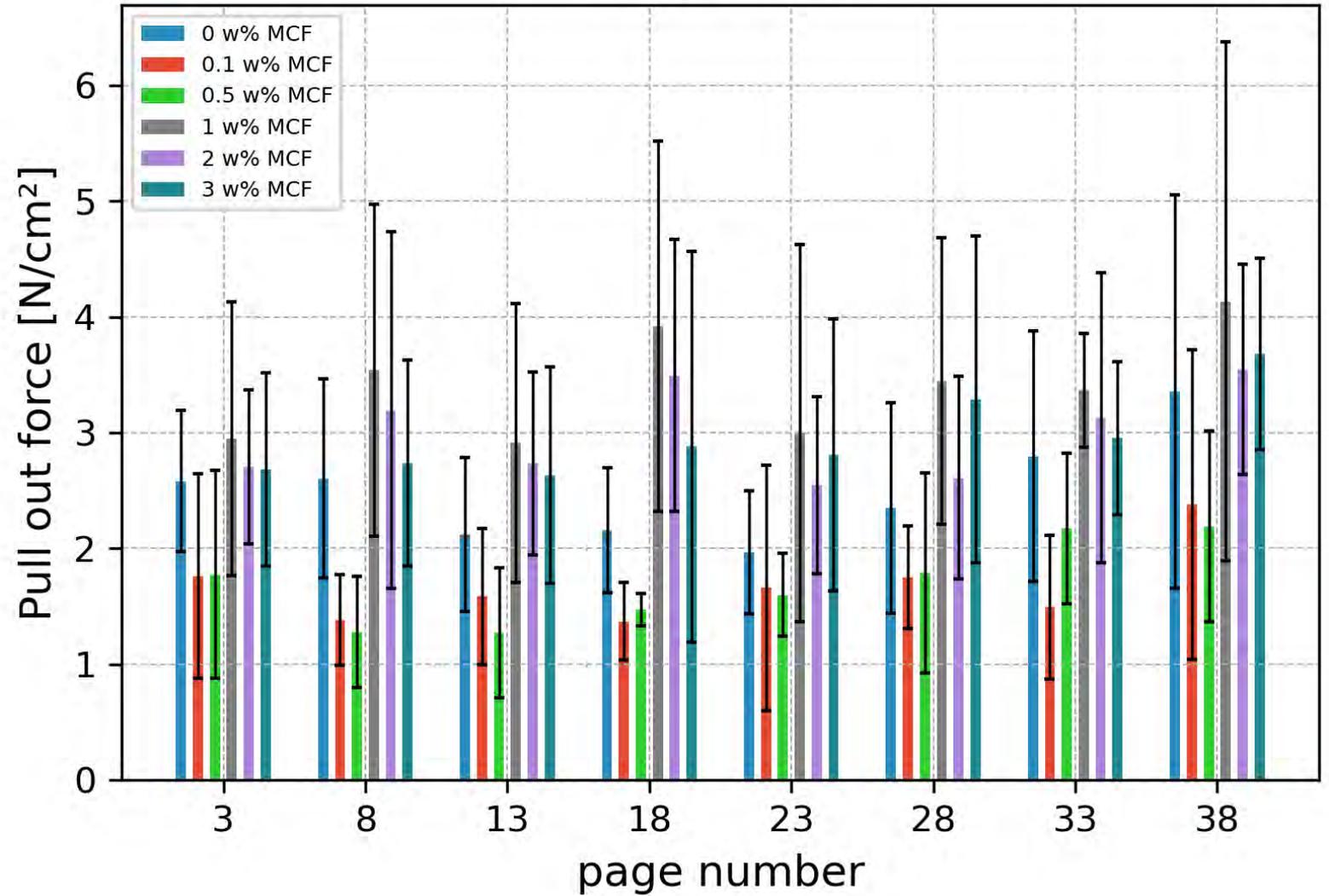
- A6 format
- 40 pages per book
- 10 books per measurement
- Good lay flat property



Results

Page	P-value
3	0.0085
8	$7.55 \cdot 10^{-6}$
13	$7.83 \cdot 10^{-5}$
18	$1.94 \cdot 10^{-6}$
23	0.0078
28	0.0006
33	$4.88 \cdot 10^{-5}$
38	0.0195

Pull test



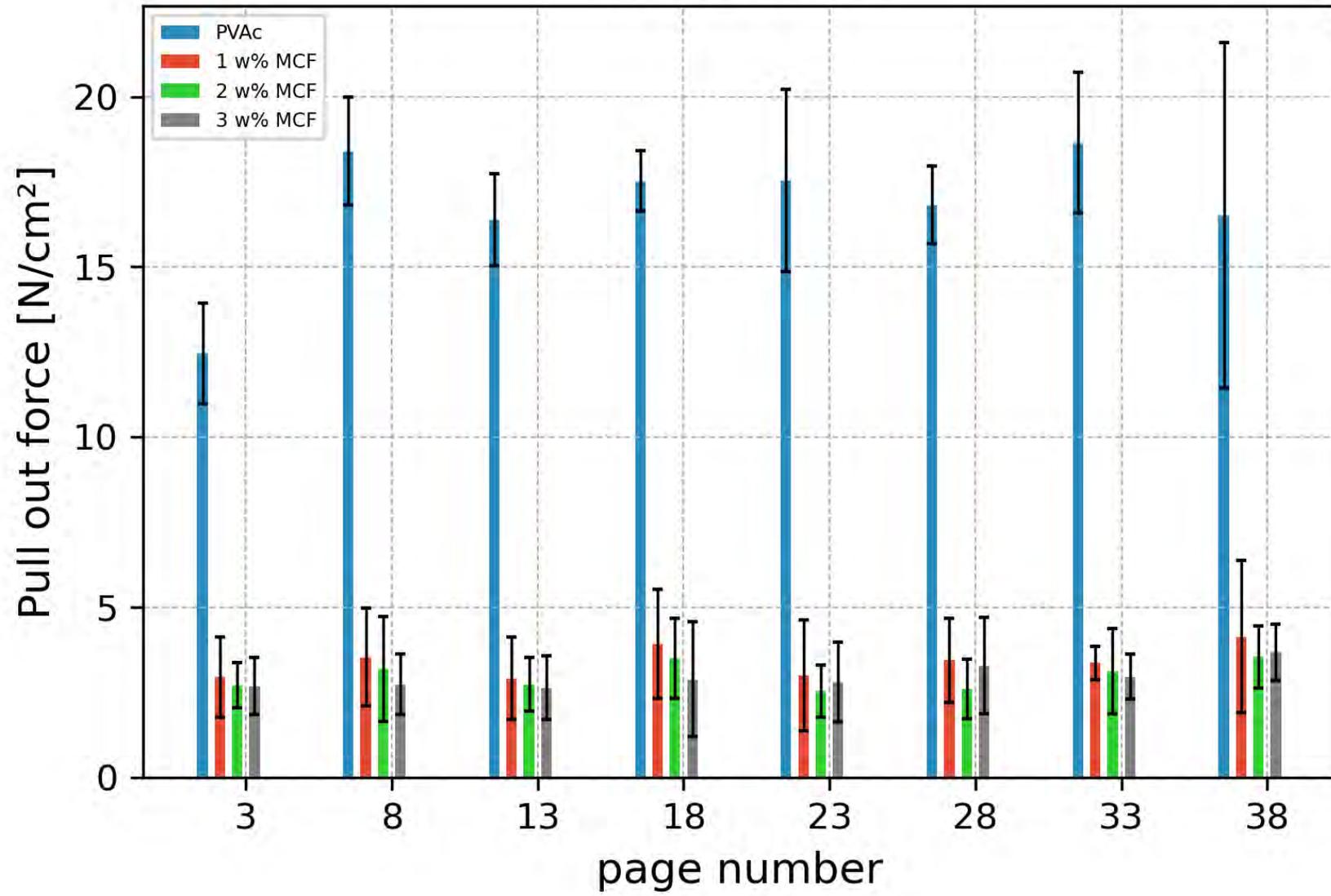
Results

Turkey HSD p-value

- A: 0w% MCF
- B: 0.1w% MCF
- C: 0.5w% MCF
- D: 1w% MCF
- E: 2w% MCF
- F: 3w% MCF

Treatment pair	Page3	Page8	Page 13	Page 18	Page 23	Page 28	Page 33	Page 38
A vs B	0.2946	0.1006	0.6738	0.5858	0.8999	0.7391	0.0123	0.6183
A vs C	0.3129	0.0599	0.2128	0.7018	0.8999	0.7843	0.5506	0.4472
A vs D	0.8999	0.3356	0.2776	0.0087	0.2187	0.1619	0.6345	0.7925
A vs E	0.8999	0.7644	0.5484	0.0850	0.7625	0.8999	0.8999	0.8999
A vs F	0.8999	0.8999	0.7044	0.6593	0.4383	0.3100	0.8999	0.8999
B vs C	0.8999	0.8999	0.8999	0.8999	0.8999	0.8999	0.4713	0.8999
B vs D	0.0374	0.0010	0.0085	0.0010	0.0499	0.0051	0.0010	0.0753
B vs E	0.1631	0.0029	0.0326	0.0010	0.3777	0.4078	0.0010	0.4434
B vs F	0.1834	0.0512	0.0655	0.3625	0.1325	0.0144	0.0035	0.3194
C vs D	0.0410	0.0010	0.0010	0.0010	0.0355	0.0065	0.0273	0.0358
C vs E	0.1751	0.0015	0.0028	0.0017	0.3039	0.4561	0.1271	0.2773
C vs F	0.1969	0.0289	0.0065	0.0608	0.0988	0.0181	0.3098	0.1865
D vs F	0.8999	0.8999	0.8999	0.8999	0.8999	0.4400	0.8999	0.8999
D vs F	0.8999	0.5035	0.8999	0.2927	0.8999	0.8999	0.8696	0.8999
E vs F	0.8999	0.8999	0.8999	0.7810	0.8999	0.6415	0.8999	0.8999

Pull test



Conclusion and outlook

- Adhesives are omnipresent in the bookbinding industry
- Petrochemical adhesives are mostly used which causes huge environmental problems
- Alginate could be a solution against the problem
- In combination with micro cellulose, shows a great viscosity and a certain adhesive strength
- Optimization is necessary
 - Overall measurements methods
 - Variation of the parameters
 - Blending with other biopolymers to improve tensile and adhesive strength
 - Adding proteins of different sources improving adhesive strength