Optimization of Microalgae Dewatering using a Britt Dynamic Drainage Jar

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Introduction

Dewatering is one of the most cost intensive processes in microalgae production. Centrifugation is considered among the most suitable dewatering techniques, however the associated energy and capital costs make it unappealing [1]. Coagulation-flocculation or dissolved air flotation and gravity sedimentation could thicken microalgae several times reducing energy demand, though also time and labour intensive. A combination of flocculation and other techniques can be suitable for microalgae harvesting [2,3]. A niche technology for biofuel scale microalgae processing is yet to be realized.

Purpose and significance

- This project is aimed to develop a microalgae dewatering process based on pulp processing techniques employed on the forming section of section of the paper machine.
- The Fourdrinier former which comprises the main part of the forming section of a paper machine is capable of processing dilute pulp stock in a concentration range of 0.1 – 3%, to yield >18 – 21% concentrate within a speed range of 250 – 1000 m/min.
- The Fourdrinier former comprises of a width of continuous moving fabric fitted on rolls underlain with hydrofoils that promote drainage, over which the pulp is distributed and run.
- The Britt Dynamic Drainage Jar (BDDJ) is an apparatus used to simulate drainage conditions of the paper machine wet-end processing. It is a useful tool for determining the shear stability of a coagulant system and assess shear effect on retention [4].
- Conditions mimicked during drainage on the BDDJ include water volume, consistency, basis weight, vacuum and turbulence [5].
- The successful application of this process in microalgae dewatering will be a significant contribution.

FIGURE 1: PAPER MACHINE FORMING SECTION (FOURDRINIER FORMER)

- The objective of this study is to investigate the laboratory scale dewatering microalgae with the aid of a coagulant systems on a Britt Dynamic Drainage Jar (BDDJ).

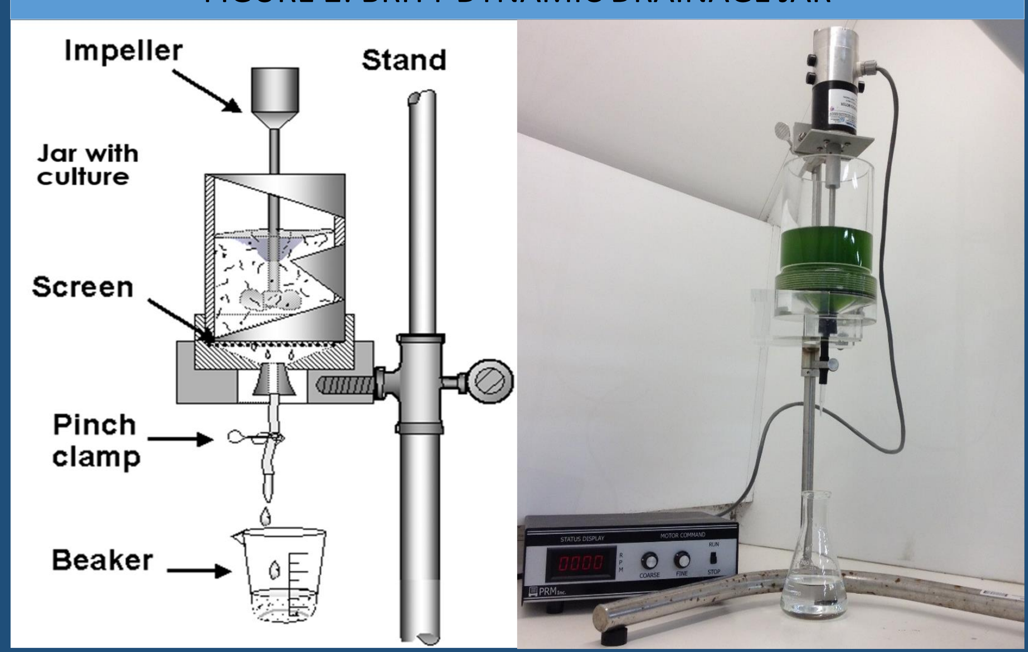
Materials and Methods

- *Nannochloropsis* species of microalgae was used to test the efficacy of the proposed technique for this filtration study.
- Microalgae samples were collected directly from an infinity pond at UQ Algae Farm in Brisbane.
- Alum ($KAl(SO_4)_2$) was used for coagulation at different concentration doses.
- The BDDJ used in this study comprises an impeller that induces turbulence, a sample jar, a 76µm sieve and a sample collection pinch clamp, which is attached to a cone shaped base.
- The procedure follows the Technical Association of Pulp and Paper Industry (TAPPI) method T261 with slight modifications.
- Response Surface Method (RSM) was used to analyse the interaction of coagulant dosage, pH and stir rate (shear) and their effect on throughput.
- A Central Composite Design (CCD) of RSM was used to design, analyse and optimize the experiment in Design Expert®.

TABLE 1: EXPERIMENTAL CONDITIONS AND CODE LEVELS

A. Coagulant Dosage (%)	B. pH	C. Stir Rate (RPM)
0.01 (-1)	4 (-1)	500 (-1)
0.03 (0)	7 (0)	750 (0)
0.05 (+1)	10 (+1)	1000 (+1)

FIGURE 2: BRITT DYNAMIC DRAINAGE JAR



Data Analysis

- For the variables investigated 20 experimental runs with varying condition combinations were conducted.
- The % of microalgae retained on the 76µm sieve was assessed as the dependent variable in the filtration.
- Model fitting was conducted using a second order polynomial equation.
- ANOVA was used to assess the interaction and contribution of the variables investigated.

Results

In this study an exploratory investigation into the effect of a coagulant system on dynamic filtration of microalgae on the BDDJ was conducted.

- Retention values ranged between 68.31 and 93.63%, from a microalgae culture of 1% consistency (10g/L).
- Comparative experiments without the addition of alum had <10% retention results.
- Each investigated variable was fitted using a second order polynomial equation with Y as the response factor.

$$\text{Retention (Y)} = +84.62 - 5.41*A*B + 4.54*B^2 - 10.24*C^2 + 3.96*A*B*C + 4.50*A*B^2$$

- The normal % probability plot indicated sample points were evenly distributed, with significant correlation between predicted and actual values ($R^2 = 0.898$).

FIGURE 3:(A) PROBABILITY DISTRIBUTION, (B) PREDICTED VS ACTUAL CORRELATION, TABLE 2: EXPERIMENTAL CONDITIONS AND RESULTS

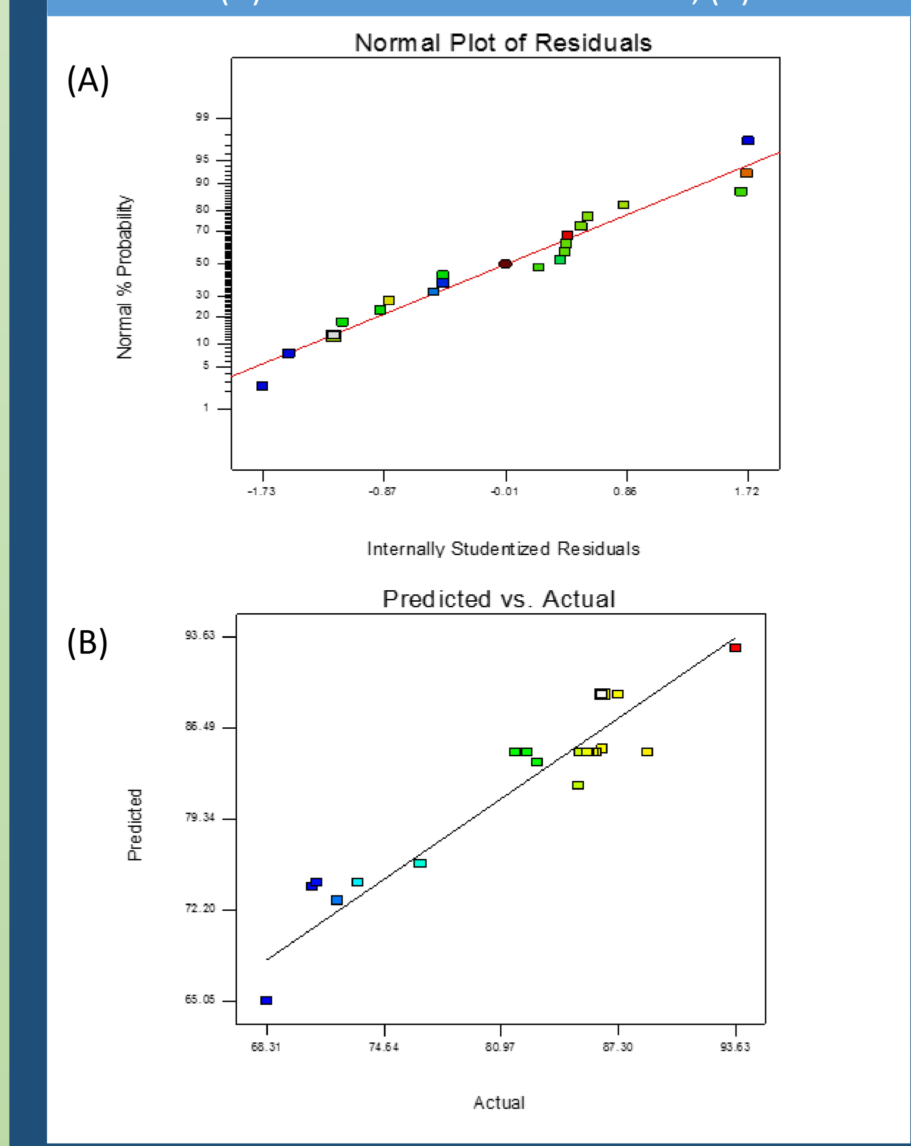


TABLE 2 S/No.	A: Coagulant dosage (%)	B: pH	C: Shear rate (RPM)	Y: Retention (%)
1	0.01	4	1000	72.12
2	0.03	7	500	73.24
3	0.03	7	750	85.66
4	0.01	7	750	85.2
5	0.03	7	750	85.95
6	0.05	10	1000	85.13
7	0.05	4	500	93.63
8	0.01	10	1000	76.61
9	0.03	10	750	86.45
10	0.03	7	750	88.88
11	0.05	4	1000	86.46
12	0.01	4	500	68.31
13	0.05	7	750	82.4
14	0.03	7	750	81.72
15	0.01	10	500	82.95
16	0.03	7	750	86.07
17	0.05	10	500	70.78
18	0.03	7	750	85.68
19	0.03	7	1000	70.97
20	0.03	4	750	87.32
17	0.05	10	500	70.78
18	0.03	7	750	85.68
19	0.03	7	1000	70.97
20	0.03	4	750	87.32

- The relationship between coagulant and pH had a linear increase, with decline in retention at higher doses.
- Improved retention on increasing shear from low to medium, while higher shear increased through pass of microalgae.
- The 3D plot showing the effects of dosage and pH on retention indicates highest retention at low pH.

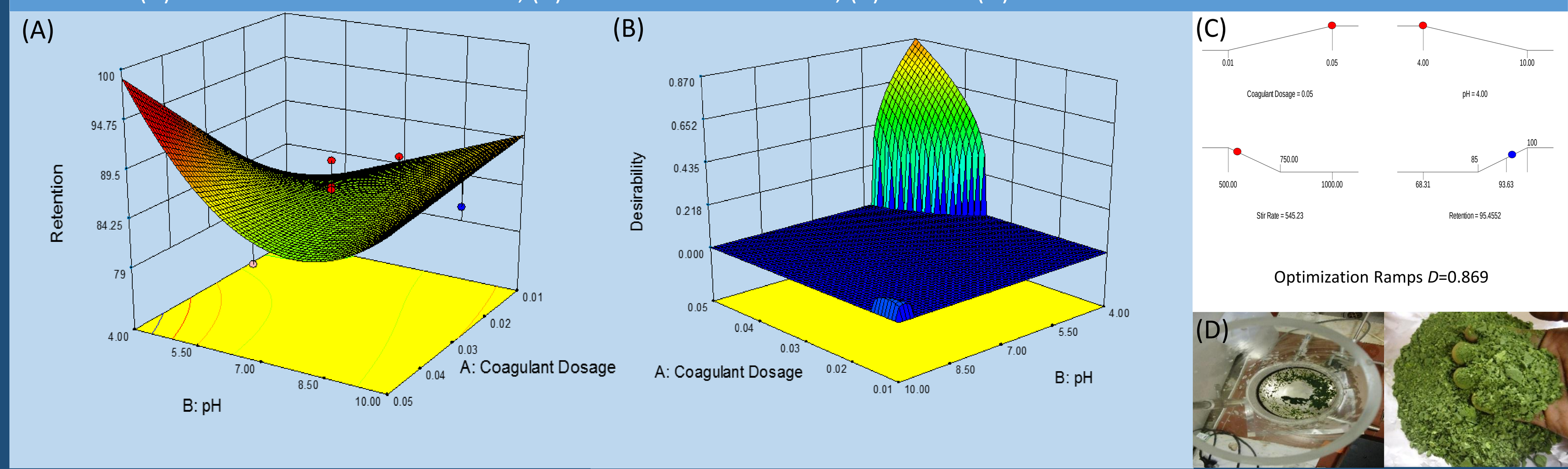
Optimization

Numerical optimization was applied to the data within the following set of targets:

- Coagulant dosage in the range 0.01 to 0.05%
- pH maximized target at 4
- Stir rate in the range 500 to 750 RPM and
- Retention targeted in the range 85 to 100%.

The desirability function (*D*) is an indicator of goal attainment in an optimization process, whose value range is 0 to 1. The desirability obtained in this study was 0.869.

FIGURE 4:(A) 3D SURFACE PLOT RETENTION, (B) 3D OPTIMIZATION PLOT, (C) RAMPS (D) SAMPLE IMAGES



Validation

Experiments were conducted in triplicate under optimum conditions as shown in the ramps to validate the predicted optimum retention value and the results were in close agreement. The predicted optimum retention was 95.46% while an experimental value of 94.8% was obtained using the same conditions.

Conclusion

- The effect of a coagulant system on shear stability during filtration was demonstrated using a BDDJ.
- Alum ($KAl(SO_4)_2$) the coagulant used in this study was effective in improving retention capacity.
- The process was suitably modelled using RSM, illustrating the interaction between variables and retention.
- The potential for microalgae dewatering using the paper industry approach is worth exploring.

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