# Optimization of Operating Conditions for Protein Production Plants using Mixed Integer Nonlinear Programming and Genetic Algorithms

## SUPPLEMENTARY MATERIAL

### Appendix A: Data Set

The experimental data of DMBP based on published data [25- 28]. The plant is divided into sub-processes, consists of six batch stages [B (1-6)] to manufacture in four products A, B, C and D.

The Table shows the values for processing times, size factor for the units, cost data, and the production requirement for each product quantifying the uncertainty on the demand. Here, we assume that the demand of products A, B, C and D are uncertain following normal probability distribution function. The data set are summarized in the following Table A1 and Table A2.

**Table A1:** Data used in the problem of batch plant design.

| S.No. | Demand of the product i(Kg) | Processing Time $T_{i,j}$ (h) | | | | | | Size Factors (1/Kg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B1 | B2 | B3 | B4 | B5 | B6 | B1 | B2 | B3 | B4 | B5 | B6 |
| A | 1500 ± 75 | 1.15 | 3.98 | 9.86 | 5.28 | 1.2 | 3.57 | 8.28 | 6.92 | 9.7 | 2.95 | 6.57 | 10.6 |
| B | 1000 ± 50 | 5.95 | 7.52 | 7.01 | 7 | 1.08 | 5.78 | 5.58 | 8.03 | 8.09 | 3.27 | 6.17 | 6.57 |
| C | 3000 ± 150 | 3.96 | 5.07 | 6.01 | 5.13 | 0.66 | 4.37 | 2.34 | 9.19 | 10.3 | 5.7 | 5.98 | 3.14 |
| D | 6000 ± 300 | 2.75 | 4.05 | 8.02 | 6.05 | 1.05 | 3.54 | 2.3 | 5.15 | 8.05 | 3.5 | 5.75 | 5.45 |
| | | 0.4 | 0.29 | 0.33 | 0.3 | 0.2 | 0.35 | | | | | | |

| | Unit prize of the product i($/Kg) | | Coefficient $c_\mu$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $C_P$ | $C_0$ | B1 | B2 | B3 | B4 | B5 | B6 | Fermentor=$63400V^{0.6}$ |
| A | 0.7 | 0.08 | 0.2 | 0.36 | 0.24 | 0.4 | 0.5 | 0.4 | Micro-and ultrafilters=$5750V^{0.6}$ |
| B | 0.74 | 0.1 | 0.15 | 0.5 | 0.35 | 0.7 | 0.42 | 0.38 | Homogenizer=$12100cap^{0.75}$ |
| C | 0.8 | 0.07 | 0.34 | 0.64 | 0.5 | 0.85 | 0.3 | 0.22 | extractor=$23100V^{0.65}$ |
| D | 0.75 | 0.05 | 0.17 | 0.45 | 0.25 | 0.67 | 0.45 | 0.25 | Chromatography=$360000V^{0.996}$ |

**Note:** Volume V in liters

| | Operation cost | | | | | | Horizontal Time H=6000h |
|---|---|---|---|---|---|---|---|
| | B1 | B2 | B3 | B4 | B5 | B6 | Lower bound=250l |
| $C_E$ | 20 | 30 | 15 | 35 | 37 | 18 | Upper bound=10000l |

**Table A2:** Cost coefficient.

| Unit | Size | Cost |
|---|---|---|
| Fermenter | $V_j$ ($m^3$) | $63400.V^{0.6}$ |
| Micro and Ultrafiter | $V_{retentate}$ ($m^3$) | $5750.V^{0.6}$ |

| | | |
|---|---|---|
| | $V_{permeate}$ ($m^3$) | $5750.V^{0.6}$ |
| | $V_{filter}$ ($m^3$) | $2900.\ V^{0.6}$ |
| Homogenizer | $V_{holding}$ ($m^3$) | $5750.V^{0.6}$ |
| | Cap ($m^3/h$) | $12100.cap^{0.75}$ |
| Extractor | $V_{extr}$ ($m^3$) | $23100.V^{0.65}$ |
| | $V_{holding}$ ($m^3$) | $5750.V^{0.6}$ |
| Chromatography column | $V_{chrom}$ ($m^3$) | $360000.V^{0.995}$ |
| Storage vessel | $V_{sto}$ ($m^3$) | $5750.V^{0.6}$ |