同时降解两种真菌毒素的食品级重组酵母培养条件优化研究

Optimization of cultivation conditions for food-grade recombinant yeast that simultaneously degrades two mycotoxins

**附表1 培养基成分单因素优化试验表**

**Supplementary Table 1 Design of single-factor optimization test for media composition**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 因素 | | 水平/（g/L） | | | | | |
| 碳源 | 葡萄糖 | 0 | 5 | 10 | 20 | 40 | 60 |
| 蔗糖 | 0 | 5 | 10 | 20 | 40 | 60 |
| 乳糖 | 0 | 5 | 10 | 20 | 40 | 60 |
| 麦芽糖 | 0 | 5 | 10 | 20 | 40 | 60 |
| 糖蜜 | 0 | 5 | 10 | 20 | 40 | 60 |
| 有机氮源 | 酵母浸粉 | 0 | 5 | 10 | 20 | 40 | 60 |
| 蛋白胨 | 0 | 5 | 10 | 20 | 40 | 60 |
| 麸皮 | 0 | 5 | 10 | 20 | 40 | 60 |
| 米糠 | 0 | 5 | 10 | 20 | 40 | 60 |
| 无机氮源 | NH4Cl | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |
| (NH4)2SO4 | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |
| 无机盐 | MgSO4 | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |
| KH2PO4 | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |
| MnSO4 | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |
| CaCl2 | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |
| KCl | 0 | 0.5 | 1.0 | 2.0 | 4.0 | 6.0 |

**附表2 培养基成分响应面优化试验因素与水平设计表**

**Supplementary Table 2 Design of response surface factors and levels for optimization test of media composition**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 水平 | 因素/（g/L） | | | | |
| *A*（葡萄糖） | *B*（蛋白胨） | *C*（酵母浸粉） | *D*（KH2PO4） | *E*（MgSO4） |
| +1 | 30.0 | 50.0 | 30.0 | 5.0 | 0.8 |
| 0 | 20.0 | 40.0 | 20.0 | 4.0 | 0.5 |
| -1 | 10.0 | 30.0 | 10.0 | 3.0 | 0.2 |

**附表3 培养参数的单因素优化试验表**

**Supplementary Table 3 Design of single factor optimization test for cultivation parameters**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 因素 | 水平 | | | | | |
| 初始pH | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 |
| 温度/℃ | 24.0 | 26.0 | 28.0 | 30.0 | 32.0 | 34.0 |
| 转速/rpm | 140 | 160 | 180 | 200 | 220 | 240 |

**附表4 培养参数的L9(34)正交试验优化设计表**

**Supplementary Table 4 Design of factors in the orthogonal test optimization for cultivation parameters**

|  |  |  |  |
| --- | --- | --- | --- |
| 编号 | *A*（初始pH） | *B*（温度）/℃ | *C*（转速）/rpm |
| 1 | 4.5 | 26 | 180 |
| 2 | 5.0 | 28 | 200 |
| 3 | 5.5 | 30 | 220 |

**附表5 响应面优化试验方案及结果**

**Supplementary Table 5 Scheme and results of response surface experiments**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 编号 | 因素及水平/（g/L） | | | | | 生物量（细胞干重）/（g/L） | |
| *A*（葡萄糖） | *B*（蛋白胨） | *C*（酵母浸粉） | *D*（KH2PO4） | *E*（MgSO4） | |  |
| 1 | 30 | 50 | 20 | 4 | 0.5 | | 5.860±0.12 |
| 2 | 10 | 40 | 20 | 4 | 0.2 | | 5.754±0.23 |
| 3 | 20 | 40 | 20 | 4 | 0.5 | | 5.962±0.40 |
| 4 | 20 | 40 | 20 | 3 | 0.8 | | 5.596±0.28 |
| 5 | 20 | 50 | 20 | 4 | 0.2 | | 5.490±0.35 |
| 6 | 20 | 40 | 10 | 5 | 0.5 | | 6.842±0.22 |
| 7 | 30 | 30 | 20 | 4 | 0.5 | | 5.956±0.51 |
| 8 | 10 | 40 | 20 | 5 | 0.5 | | 5.446±0.33 |
| 9 | 20 | 40 | 20 | 5 | 0.2 | | 6.012±0.41 |
| 10 | 10 | 50 | 20 | 4 | 0.5 | | 5.018±0.19 |
| 11 | 30 | 40 | 20 | 4 | 0.2 | | 6.024±0.24 |
| 12 | 20 | 40 | 20 | 3 | 0.2 | | 6.498±0.43 |
| 13 | 20 | 40 | 20 | 5 | 0.8 | | 6.104±0.26 |
| 14 | 20 | 40 | 20 | 4 | 0.5 | | 6.126±0.22 |
| 15 | 20 | 50 | 30 | 4 | 0.5 | | 5.608±0.29 |
| 16 | 10 | 40 | 30 | 4 | 0.5 | | 5.599±0.36 |
| 17 | 10 | 40 | 20 | 3 | 0.5 | | 5.692±0.30 |
| 18 | 20 | 30 | 10 | 4 | 0.5 | | 5.792±0.52 |
| 19 | 20 | 50 | 10 | 4 | 0.5 | | 5.454±0.46 |
| 20 | 30 | 40 | 30 | 4 | 0.5 | | 5.732±0.18 |
| 21 | 10 | 30 | 20 | 4 | 0.5 | | 5.288±0.23 |
| 22 | 10 | 40 | 20 | 4 | 0.8 | | 5.012±0.31 |
| 23 | 30 | 30 | 20 | 4 | 0.2 | | 6.016±0.44 |
| 24 | 40 | 40 | 30 | 4 | 0.8 | | 5.754±0.38 |
| 25 | 40 | 40 | 30 | 3 | 0.5 | | 6.720±0.29 |
| 26 | 20 | 40 | 30 | 4 | 0.2 | | 5.794±0.20 |
| 27 | 30 | 40 | 20 | 4 | 0.8 | | 5.990±0.50 |
| 28 | 30 | 40 | 20 | 3 | 0.5 | | 6.217±0.34 |
| 29 | 20 | 30 | 20 | 3 | 0.5 | | 6.274±0.35 |
| 30 | 20 | 30 | 20 | 4 | 0.8 | | 5.394±0.39 |
| 31 | 20 | 40 | 20 | 4 | 0.5 | | 6.138±0.26 |
| 32 | 30 | 40 | 20 | 5 | 0.5 | | 6.328±0.19 |
| 33 | 20 | 40 | 10 | 4 | 0.8 | | 5.442±0.48 |
| 34 | 20 | 30 | 30 | 4 | 0.5 | | 5.498±0.42 |
| 35 | 20 | 40 | 20 | 4 | 0.5 | | 6.298±0.28 |
| 36 | 20 | 40 | 30 | 5 | 0.5 | | 5.154±0.44 |
| 37 | 30 | 40 | 10 | 4 | 0.5 | | 6.260±0.32 |
| 38 | 20 | 50 | 20 | 3 | 0.5 | | 5.598±0.26 |
| 39 | 20 | 50 | 20 | 5 | 0.5 | | 6.156±0.14 |
| 40 | 20 | 40 | 20 | 4 | 0.5 | | 6.180±0.25 |
| 41 | 20 | 50 | 20 | 4 | 0.8 | | 5.596±0.27 |
| 42 | 20 | 30 | 20 | 5 | 0.5 | | 5.396±0.36 |
| 43 | 20 | 40 | 10 | 3 | 0.5 | | 5.234±0.45 |
| 44 | 10 | 40 | 10 | 4 | 0.5 | | 5.048±0.37 |
| 45 | 20 | 40 | 10 | 4 | 0.2 | | 6.190±0.32 |

**附表6 响应面试验的方差分析**

**Supplementary Table 6 Variance analysis of the established regression equation**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 来源 | 平方和 | 自由度 | 均方根 | F值 | Prob>F | 显著性 |
| Model | 8.25 | 20 | 0.4123 | 69.28 | < 0.0001 | \*\* |
| A-Glucose | 1.90 | 1 | 1.90 | 318.75 | < 0.0001 | \*\* |
| B-Peptone | 0.0435 | 1 | 0.0435 | 7.30 | 0.0124 | \* |
| C-Yeast Extract | 0.0093 | 1 | 0.0093 | 1.56 | 0.0122 | \* |
| D-KH2PO4 | 0.0105 | 1 | 0.0105 | 1.76 | 0.0197 | \* |
| E-MgSO4 | 0.5220 | 1 | 0.5220 | 87.71 | < 0.0001 | \*\* |
| AB | 0.0076 | 1 | 0.0076 | 1.27 | 0.2706 |  |
| AC | 0.2911 | 1 | 0.2911 | 48.90 | < 0.0001 | \*\* |
| AD | 0.0319 | 1 | 0.0319 | 5.35 | 0.0296 | \* |
| AE | 0.1253 | 1 | 0.1253 | 21.06 | 0.0001 | \*\* |
| BC | 0.0502 | 1 | 0.0502 | 8.43 | 0.0078 | \* |
| BD | 0.5155 | 1 | 0.5155 | 86.62 | < 0.0001 | \*\* |
| BE | 0.1325 | 1 | 0.1325 | 22.26 | < 0.0001 | \*\* |
| CD | 2.49 | 1 | 2.49 | 418.38 | < 0.0001 | \*\* |
| CE | 0.1253 | 1 | 0.1253 | 21.06 | 0.0001 | \*\* |
| DE | 0.2470 | 1 | 0.2470 | 41.50 | < 0.0001 | \*\* |
| A² | 0.6246 | 1 | 0.6246 | 104.94 | < 0.0001 | \*\* |
| B² | 0.9756 | 1 | 0.9756 | 163.92 | < 0.0001 | \*\* |
| C² | 0.3380 | 1 | 0.3380 | 56.79 | < 0.0001 | \*\* |
| D² | 0.0276 | 1 | 0.0276 | 4.65 | 0.0414 | \* |
| E² | 0.2004 | 1 | 0.2004 | 33.67 | < 0.0001 | \*\* |
| 残差 | 0.1428 | 24 | 0.0060 |  |  |  |
| 失拟项 | 0.0844 | 20 | 0.0042 | 0.2888 | 0.9736 |  |
| 纯误差 | 0.0584 | 4 | 0.0146 |  |  |  |
| 合计 | 8.39 | 44 |  |  |  |  |
|  | R2=0.9830 |  | R2(adj)=0.9688 |  |  |  |

注：\*表示显著，P<0.05；\*\*表示非常显著，P<0.01