

放線菌 *Arthrobacter enclensis* TCC-2 之 多功能羽毛分解特性及促進有機栽培萵苣生長之研究¹

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摘 要

本研究篩選羽毛分解菌 *Arthrobacter enclensis* TCC-2，培養於基本礦物鹽培養基(含1% 羽毛，w/v)至第4天其羽毛分解率為65.3%，羽毛分解液具多種游離胺基酸，其中以含硫胺基酸及支鏈胺基酸含量最多，菌株TCC-2培養於含tryptophan之NB培養基12小時可生成134.6 mg/L之IAA，具有促進作物生長之潛力，且菌株具有耐鹽能力，於6%氯化鈉之培養條件下菌數可達 10^8 CFU/mL，具有與化學肥料混用之潛力。菌株培養於1%羽毛、0.5%磷礦石粉與0.5%草木灰，經培養4天後，羽毛結構已完全分解，分解液之電導度值與可溶性氮含量較未接菌者顯著提升，菌數可達 10^9 CFU/mL且具有溶解磷酸三鈣與磷礦石粉之能力，將此分解液施用至有機栽培萵苣可促進萵苣生長並提高植體磷含量，於基肥施用120公斤氮素/公頃之菜籽粕用量，搭配澆灌菌液可提高有機萵苣產量。

關鍵詞：*Arthrobacter enclensis*、羽毛分解、溶磷、耐鹽、吡啶乙酸、有機萵苣。

前 言

氮為作物生長所需，有機栽培常以氮質海鳥糞或豆粕做為氮肥補充，然其價高昂。羽毛可做為替代氮源，提供作物所需氮素⁽¹²⁾，然而因羽毛角蛋白質含量豐且其雙硫鍵多結構緊密，因此不易分解，無法快速釋放氮素供作物利用，另應用於飼料添加之研究指出，以高溫高壓處理羽毛以作為飼料添加，常因胺基酸結構破壞，如methionine、lysine及tryptophan易受破壞，而導致其作為飼料添加之營養價值減損⁽³²⁾。微生物轉換羽毛廢棄物將可避免胺基酸遭破壞，可提高飼料添加之價值或作為相對速效之氮質肥料施用^(4,7,11,12,15,21)。

磷為作物生長所需之必要元素，然因磷肥施用至土壤後易形成磷酸鈣、磷酸鋁及磷酸鐵沉澱而降低磷之植物有效性^(2,31)，若因磷之植物有效性低而大量施用磷肥，則會導致施肥成本增加且造成環境汙染⁽²⁵⁾。溶磷菌可經由產酸、鉗合及氧化還原等作用而溶解難溶性磷^(6,10)。近來由於肥料價格高漲及其他產業對磷礦的需求增加，如食物防腐添加、殺真菌劑應用、製陶業、冶金業等，使得高品質磷礦分配至農業應用的機會降低。因此，本研究目的是以溶磷菌進行土壤磷之溶出以提高作物利用率，有利於達農業之永續發展⁽⁹⁾。

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材料與方法

篩選具溶磷能力之羽毛分解菌株及菌種鑑定

本研究採取中興大學中興湖周邊之土壤，添加10 g於95 ml含有1%雞羽毛(取自興中台股份有限公司)及0.5%磷酸三鈣(Calcium phosphate tribasic, KATAYAMA)之去離子水中，經室溫培養5天後以十倍連續稀釋塗抹於BHF (含1%羽毛，w/v)固態培養基中，BHF培養基為參考BH基本礦物鹽培養基⁽⁵⁾，並經修改其配方為每1L去離子水含有1 g磷酸氫二鉀、1 g磷酸二氫鉀、0.2 g硫酸鎂(含7個結晶水)及0.02 g氯化鈣並添加1% (w/v)之羽毛。羽毛先經由刀片切割機(原泰奇機械DM6)切割約20秒後備用。經培養3~5天後，進行純化培養並挑選單一菌落接種至液態磷酸三鈣或磷礦石粉(Rock-P, CCM FERTILIZER Sdn Bhd)培養基，經培養4天後以鉬藍法⁽³³⁾進行水溶性磷含量分析，以篩選溶磷菌株並分析其溶磷量。磷酸三鈣培養基及磷礦石粉培養基之配方參照肥料檢驗方法(方法編號AFS3183-1)。接種篩選之溶磷菌株單一菌落至BHF液態培養基中，於室溫培養4天後觀察羽毛分解狀況，以篩選出具溶磷能力之羽毛分解菌。本研究配製之培養基皆經高溫及高壓滅菌處理。篩選之菌株委託財團法人食品工業發展研究所進行菌種鑑定。

羽毛分解液之pH、EC、元素養分及菌落數分析

本研究接種篩選菌株之單一菌落於50 ml BHF培養基中，於30℃及120 rpm震盪培養4天後，以十倍連續稀釋法，取樣100 µl塗抹於nutrient broth (NB)固態培養基中，培養3天後計算菌落數。另其培養液經預先以70℃烘乾至恆重之Whatman No.1濾紙過濾後，其濾液以電極分析pH及EC，銨態氮及全氮以微量擴散法測定⁽¹⁴⁾，鉀以火焰光度計測定(Sherwood flame photometer 410)，磷以鉬藍法測定⁽³³⁾，而鈣及鎂則用原子吸收光譜儀(Hitachi Polarized Zeeman Atomic absorption spectrophotometer Z-5000)分析。濾紙上殘留之羽毛經70℃烘乾至恆重後秤重，經與對照處理(未接菌之培養基)之殘留重量比較後，計算羽毛分解率。以上處理皆以3重複進行試驗。統計分析以Least Significance difference (LSD)法進行比較，表中相同字母表示彼此間無顯著差異(p=0.05)。

菌株TCC-2之羽毛分解液游離胺基酸分析

本研究接種單一菌落於BHF羽毛培養基經培養4天後，進行游離胺基酸分析，以瞭解篩選菌株之羽毛分解特性及其做為其他應用之參考，本研究委由嘉義大學檢驗分析及技術推廣服務中心進行分析。

菌株耐鹽特性分析

本研究配製0%、3%、5%、6%、7%及8%氯化鈉之NB培養基(5 mL)，經接種篩選菌株單一菌落於此培養基，經室溫震盪(110 rpm)培養24小時後測定培養液pH及EC值，並連續稀釋塗抹於NB固態培養基，培養3天後計算菌落數。

菌株生成IAA (indole-3-acetic acid)能力分析

菌株生成IAA能力分析以配製分析培養基為10 g蔗糖、1 g硝酸銨、1 g磷酸二氫鉀、1 g磷酸氫二鉀、0.2 g硫酸鎂(含7個結晶水)及0.02 g氯化鈣、0.001 g硫酸亞鐵(含7個結晶水)和0.001 g硫酸錳(含4個結晶水)於1 L去離子水，並添加已過濾滅菌之tryptophan，使其最終濃度為1 mg/mL (培養基1)。另配製含有1 mg/mL tryptophan之NB培養基(培養基2)。經接種菌株於5 mL培養基1，培養48小時而接種菌株於培養基2，培養12小時後，以8,000 g離心15分鐘後，取1 mL上清液添加4 mL之Salkowski reagent⁽¹⁹⁾，混合均勻後於室溫暗室中反應30分鐘，並分析540 nm之吸光值，對照組為1 mL未接菌培養基加4 mL之Salkowski reagent。有IAA生成則與試劑反應後之顏色轉紅，並呈現在540 nm之吸光值的增加。另以IAA配製並製作標準曲線以轉換540 nm吸光值為IAA濃度。

配製應用於有機萵苣肥料試驗之羽毛分解菌液

本研究配製1%完整羽毛、0.5%磷礦石粉(Rock-P, CCM FERTILIZER Sdn Bhd, 30%總磷酐)與0.5%草木灰(油棕灰購自益欣股份有限公司)之50 mL與500 mL液態培養基，50 mL培養基添加0.5 g羽毛、0.25 g磷礦石粉及0.25 g草木灰並加50 mL去離子水，500 mL培養基組成50 mL培養基組成10倍用量。接種菌株TCC-2之單一菌落於50 mL培養基，於30℃、120 rpm培養4天後，進行過濾液養分分析、菌數分析(分析方法如前所述)與溶磷活性分析，其分析方法參考肥料檢驗方法(方法編號AFS3183-1)，取100 μ L菌液添加於50 mL磷酸三鈣與磷礦石粉培養基(5 g/L)，於30℃、120 rpm震盪培養5天後，其菌液經離心與過濾後，以鉬藍法測定過濾液之磷含量，對照組為將菌液滅菌後，與上述相同方法進行分析，溶磷量為實驗組之可溶性磷含量減去對照組之可溶性磷含量。另取50 mL菌液將其放大培養於500 mL之培養基，於室溫110 rpm震盪培養4天後備用。

有機栽培萵苣肥料試驗

有機福山萵苣肥料試驗於本場有機試驗區進行，試驗前進行土壤肥力分析，試驗田區分成4級氮素處理，分別為N0、N60、N120及N180 kg-N/ha，以菜籽粕(7-3-1.5)經公式(菜籽粕施用量=氮素用量÷菜籽粕氮素含量÷80%預估礦化率÷90%乾物量)計算成相等之氮素量。基肥全區施用65 kg磷礦石粉(30%總磷酐)/分地及各級氮素之菜籽粕用量後，耕犁入土並作畦，每氮素處理作4畦，畦寬120 cm，畦長約47 m，每畦種植2行幼苗，株距50 cm，定植後每一氮素處理區分成澆灌菌液與否。幼苗於定植前一天，澆灌100倍稀釋菌液，並於定植後第15、23及31天每株澆灌100倍稀釋菌液100 mL，於35天後進行採收調查與植體養分分析。植體以濃硫酸及雙氧水消化分解⁽¹⁸⁾，氮用微量擴散法測定⁽¹⁴⁾，磷用比色法定量⁽²⁰⁾，鉀用火焰光度計測定(Sherwood flame photometer 410)，鈣及鎂則用原子吸收光譜儀(Hitachi Polarized Zeeman Atomic absorption spectrophotometer Z-5000)分析。微量元素銅、錳、鋅及鐵則以1 N鹽酸反應⁽³⁶⁾並以原子吸收光譜儀分析。土壤分析為樣品先經風乾處理，經2 mm篩網過篩後分別測定土壤化學性質，土壤pH及電導度以水：土比1:1，分別以電極法測定。土壤有機質含量採用總有

機碳分析儀(Elementar vario MAX C)測定。以1M醋酸銨(pH 7.0)，土：溶液比1:10抽出^(16,17)，濾液用感應耦合電漿光譜分析儀(Inductively Coupled Plasma-Atomic Emission Spectrometry; ICP-AES, HORIBA JOBIN- YVON ULTIMA 2)測土壤交換性鉀、鈣及鎂含量。以Bray No.1方法抽取⁽²⁰⁾，並用感應耦合電漿光譜分析儀測土壤有效性磷。土壤微量元素以0.1 N鹽酸萃取⁽¹⁾並以感應耦合電漿光譜分析儀測定。

結果與討論

篩選菌株之菌種鑑定、羽毛分解與溶磷能力分析

本研究篩選具溶磷能力之羽毛分解菌株TCC-2，分析比對其16S rDNA序列(1506 bp)與*Arthrobacter enclensis* 相似度達99.1%，菌種鑑定為*Arthrobacter enclensis*。菌株TCC-2單一菌落培養於磷酸三鈣及磷礦石粉之培養基，經培養4天，自磷酸三鈣溶出之可溶性磷為 8.51 ± 0.01 mg/L而自磷礦石粉溶出之可溶性磷為 2.34 ± 0.22 mg/L。菌株TCC-2培養於BHF培養基至第4天，其羽毛分解率為65.3%，菌數可達 10^9 CFU/mL，其pH、EC與全氮含量較對照組顯著增加，顯示羽毛轉化分解(表一)。

表一、菌株 TCC-2 培養於 BHF 培養基 4 天後之元素養分含量、菌數及羽毛分解率之變化

Table 1. The variation of nutrient content, bacteria number and feather degradation rate (%) at 4 days after incubated with *Arthrobacter enclensis* TCC-2 in BHF medium

Isolates	pH	EC (mS/cm)	NH ₄ ⁺ (mg/L)	Tot-N (%)	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Degradation rate %	Bacteria number 10 ⁹ *CFU/mL
C-2	8.32 ± 0.06 (SD)	4.09 ± 1.11	535.95 ± 38.25	0.55 ± 0.015	533.43 ± 11.92	767.5 ± 13.44	1.8 ± 0.14	4.7 ± 0.57	65.3 ± 0.7	4.37 ± 0.45
CK	6.78 ± 0.04	1.69 ± 0.59	11.4 ± 0.85	0.014 ± 0.001	413.50 ± 7.78	717.6 ± 41.65	1.85 ± 0.35	17.4 ± 0.14	-	-

菌株TCC-2之分解羽毛液之游離胺基酸分析

本研究分析菌株TCC-2培養於BHF培養基之羽毛分解液中，其游離胺基酸組成及濃度，如表二所示，結果顯示含硫胺基酸如methionine及cysteine含量豐富，前人研究提及含硫胺基酸對幼雛動物生長而言是十分重要的營養源^(24,29)，或可作為飼料開發之應用。此外此菌株之羽毛分解液中的支鏈胺基酸含量豐富(branched-chain amino acid, BCAA)，如leucine、isoleucine與valine，為此菌株分解羽毛之特點。前人研究指出初生且剛斷奶的小豬，容易因腹瀉導致死亡而減少養豬業之經濟效益⁽²⁷⁾，減少飲食的蛋白質含量雖可有效控制腹瀉發生頻率與嚴重程度^(22,34)，然而卻會因胺基酸供應不平衡而導致豬隻生育不良⁽³⁵⁾。研究指出餵養幼豬低蛋白質飼料會減低豬隻每日平均增重量與換肉率，然而若以低蛋白質飼料添加BCAA則其每日平均

增重量及換肉率與餵養正常蛋白質飼料之處理組無顯著差異⁽³⁷⁾，另有研究指出幼豬餵養低蛋白質飼料添加BCAA可提高腸道免疫力並增進豬隻生長⁽²⁶⁾，顯示BCAA於豬隻飼料添加之價值。本研究篩選菌株之羽毛分解液中，含有相對高量之BCAA具有作為低蛋白質飼料添加之應用效益，可作為往後研究應用之參考。

表二、菌株 TCC-2 培養於 BHF 培養基 4 天後之游離胺基酸分析

Table 2. The variation of free amino acids in BHF medium at 4 days after incubated with *Arthrobacter enclensis* TCC-2

Amino acids	Conc. µg/g
Arginine	3.27
Asparatic acid	ND
Cysteine	55.4
Glutamic acid	8.57
Glycine	0.29
Histidine	0.25
Isoleucine	16.80
Leucine	85.33
Lysine	ND
Methionine	99.32
Phenylalanine	ND
Proline	0.34
Serine	3.31
Threonine	1.39
Tryosine	1.62
Valine	45.34

菌株TCC-2之耐鹽能力與IAA生成能力的分析

本研究篩選之菌株*Arthrobacter enclensis* TCC-2經培養於含有tryptophan基本礦物鹽培養基，培養48小時後，可生成IAA 10.8 ± 2.29 mg/L，而培養於含tryptophan之NB培養基12小時後，可生成IAA 134.6 ± 26.4 mg/L，結果顯示菌株TCC-2可利用tryptophan為基質轉換生成促進植物生長之荷爾蒙IAA，施用至作物根圈，應有助於促進作物根系生長，提高養分利用率。前人研究提及菌株具分泌植物賀爾蒙如IAA可促進根系生長並增加作物生產^(23,28)，許多具溶磷能力之羽毛分解菌如*Bacillus subtilis* S8, *Bacillus cereus* TS1與*Bacillus cereus* PM2皆具有生成IAA能力^(3,13,30)，其中*Bacillus cereus* TS1培養於含0.2 mM tryptophan之NB培養基至第2天，可生成10.21 mg/L的IAA而*Bacillus cereus* PM2培養於含有500 µg/mL tryptophan之minimal salt培養基至第4天，可生成21.0 mg/L IAA，相較而言本研究篩選菌株TCC-2可於較短培養時間生成相對多量之IAA，微生物具有生成IAA之能力，有助於提高其作為微生物肥料應用效益。

Arthrobacter enclensis TCC-2接種於不同氯化鈉濃度之液態NB培養基，經培養24小時，其菌液之pH、EC與菌數如表三所示，結果顯示經培養24小時後，接種菌株TCC-2可提高NB培養液之pH值，推測可能為此菌株具分解蛋白質與產氨能力所致。未添加或含有3%氯化鈉之培養基中，其菌數可達 10^9 CFU/mL，而添加氯化鈉至6%其菌數仍達 10^8 CFU/mL，結果顯示菌株TCC-2具有耐鹽特性，可應用於與化學肥料混用之潛力。*Arthrobacter enclensis* (type strain NIO-1008^T)為學者自海洋層積物中篩選之新菌種⁽⁸⁾，與本研究篩選菌株TCC-2之耐鹽特性應具有演化上相關性。

表三、菌株 TCC-2 培養於不同濃度氯化鈉培養基 24 小時之 pH、EC 及菌數分析

Table 3. The variation of pH, EC and bacteria numbers of NB broth with different concentrations of NaCl at 24 hrs after incubated with strain TCC-2

Item	Treatment	NaCl %/Inoculant					
		0	3	5	6	7	8
pH	CK	6.88	6.65	6.51	6.53	6.56	6.46
	TCC-2	8.28	7.65	7.49	7.11	6.66	6.53
EC (mS/cm)	CK	1.48	37.2	57.6	67.2	76.6	82.0
	TCC-2	1.84	40.2	46.6	63.8	69.5	84.2
Bacterial number 10^8 *CFU/mL	TCC-2	37±2 (SD)	11±0.3	3.65±1.35	1.21±0.05	0.34±0.07	0.42±0.01

菌株TCC-2之溶磷微生物肥料開發與促進有機栽培萵苣之生長

菌株TCC-2培養於1%羽毛+0.5%磷礦石粉+0.5%草木灰，經培養4天後，其羽毛分解液之養分特性如表四所示，其分解液之菌數可達 10^9 CFU/mL且於此羽毛分解液中之菌株TCC-2具有溶磷能力。有機栽培福山萵苣試驗前土壤肥力如表五所示，土壤pH偏中鹼性，磷與鉀含量偏低，因此試驗前施用磷礦石粉，並搭配澆灌菌液，以期提高土壤中植物有效性磷含量。福山萵苣植株性狀如表六所示，株高以N180處理組最高，以N120+TCC-2最低，株寬以N0+TCC-2最低，而不施肥處理組(N0)經澆灌菌液(N0+TCC-2)後可顯著增加葉片數，而施肥處理組施用菌與否對葉片數無顯著影響。未施肥處理組經澆灌菌液處理可顯著增加單株鮮重(N0+TCC-2)，而N60處理組與N180處理組澆灌菌液與否彼此間之鮮重無顯著差異，N120處理組則因澆灌菌液而顯著增加萵苣鮮重且達最高為248.9 g/plant。若比較未加菌而施用不同肥料量(N0、N60、N120與N180)之萵苣鮮重，結果顯示隨菜籽粕施用量增加對提升萵苣鮮重之功效並不顯著，推測原因為畦面覆蓋銀黑布降低菜籽粕分解效率所致。然而若搭配澆灌菌液(N0+TCC-2、N60+TCC-2、N120+TCC-2與N180+TCC-2)，則與未施肥組(N0)相比皆可提昇萵苣鮮重，結果顯示澆灌菌液可促進萵苣生長。

萵苣葉片養分分析結果如表七所示，其葉片磷含量因澆灌菌液有些微提昇，而以N60處理組經澆灌菌液可顯著提升植體磷含量，推測為溶磷菌發揮溶磷功能所致，而植體鉀含量以N120+TCC-2處理組最高，植體鎂含量隨肥料用量增加而增加，以N60澆菌處理組高於未澆菌

處理組，植體銅含量以N120澆菌處理組顯著高於未澆菌處理組，植體氮、鈣、錳與鐵含量於各級氮肥處理間，不因澆菌與否有顯著差異。本研究結果顯示基肥施用120公斤氮素/公頃之菜籽粕搭配澆灌羽毛分解菌液可達萵苣最高單株鮮重與產量。

表四、菌株培養於 1%羽毛、0.5%磷礦石粉及 0.5%草木灰至第 4 天之羽毛分解液元素養分、菌數及溶磷活性變化

Table 4. The variation of bacteria number and nutrient content at 4 days after incubated in culture medium contained with 1% feather, 0.5% rock phosphate and 0.5% plant ash

Strains	Bacterial number (10 ⁹ *CFU/mL)	Soluble P from Ca-P (mg/L)	Soluble P from Rock-P (mg/L)	pH	EC (mS/cm)	NH ₄ ⁺ (mg/L)	Tot-N (%)	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)
TCC-2	2.8 ±0.3(SD)	54.9 ±0.89	4.05 ±0.22	8.6 ±0.02	4.30 ±0.50	205.33 ±41.79	0.274 ±0.037	8.22 ±0.87	1218.4 ±122.7	5.53 ±1.80	3.77 ±0.64
CK	-	-	-	8.85 ±0.25	3.27 ±0.39	12.00 ±2.00	0.052 ±0.016	5.82 ±0.26	1228.9 ±105.8	2.43 ±1.01	2.90 ±2.14

表五、有機栽培田試驗前土壤肥力

Table 5. Chemical properties of soil in organic farmland at the beginning of this experiment

pH	EC	OM	Tot-N	P	K	Ca	Mg	Cu	Mn	Zn	Fe
1:1	1:1 dS/m	%	%	ppm							
7.59	0.21	1.9	0.134	38	29	1164	178	5	77	7	473

表六、添加羽毛分解液對有機栽培萵苣生長與產量之影響

Table 6. Effects of feather hydrolysates on growth and yield of organic lettuce

Treatment	Plant height (cm)	Plant width (cm)	Leaf number per plant	Fresh weight (g/plant)	Yield (g/m ²)
N0 ²	15.7bc ¹	23.9a	24.2b	176.9d	402.3c
N0+TCC-2 ³	15.7bc	21.0b	28.0a	208.5bc	474.2bc
N60	16.9ab	24.6a	27.8a	203.4bcd	462.6bc
N60+TCC-2	16.4abc	24.4a	29.6a	229.6ab	522.2ab
N120	16.8abc	24.2a	27.3ab	201.2bcd	457.6bc
N120+TCC-2	15.4c	25.3a	29.0a	248.9a	566.0a
N180	17.2a	25.1a	28.7a	197.0cd	448.0bc
N180+TCC-2	16.6abc	24.8a	28.8a	223.0abc	507.2ab

¹ In lines, means followed by the same letter are not significantly difference at P = 0.05 (LSD test).

² N0, N60, N120 and N180 represented different nitrogen amount used in organic farmland.

³ TCC-2 represented feather hydrolysates after incubation with *Arthrobacter enclensis* TCC-2.

表七、不同處理之萵苣葉片元素養分分析

Table 7. The nutrient content of lettuce leaf grown in different treatments

Treatment	N	P	K	Ca	Mg	Cu	Mn	Zn	Fe
	%			ppm					
N0 ²	2.30a ¹	0.36b	3.80ab	1.22a	0.43c	10.7bc	26.3bc	30.7cd	375.3b
N0+TCC-2 ³	2.18a	0.40ab	3.78ab	1.21a	0.42c	10.0c	25.0bc	29.7d	316.3b
N60	2.21a	0.37b	3.57b	1.20a	0.46bc	10.7bc	26.3bc	35.3bc	671.3ab
N60+TCC-2	2.40a	0.45a	3.66b	1.18a	0.55a	11.7ab	32.3ab	39.7ab	756.7ab
N120	2.43a	0.37b	3.61b	1.40a	0.56a	11.0bc	29.7abc	35.0bcd	624.0ab
N120+TCC-2	2.51a	0.42ab	4.4a	1.69a	0.54a	12.3a	35.3a	42.0a	935.3a
N180	2.53a	0.40ab	4.12ab	1.46a	0.50ab	10.3c	28.3abc	35.7bc	478.7ab
N180+TCC-2	2.55a	0.42ab	3.66b	1.30a	0.47bc	10.7bc	22.7c	35.7bc	360.0b

¹ In lines, means followed by the same letter are not significantly difference at P = 0.05 (LSD test).

² N0, N60, N120 and N180 represented different nitrogen amount used in organic farmland.

³ TCC-2 represented feather hydrolysates after incubation with *Arthrobacter enclensis* TCC-2. incubation of *Arthrobacter enclensis* TCC-2.

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Study on the Feather-degrading Efforts of *Actinobacterium Arthrobacter enclensis*, TCC-2 and Its Stimulating Growth Performance on Organic Lettuce¹

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ABSTRACT

The tested feather-degrading bacterium was isolated and identified as *Arthrobacter enclensis* TCC-2 in this study. Through the incubating the strain TCC-2 in basal medium with 1% feather (w/v), the result shown that the feather degradation rate was 65.3% and various free amino acids were detected in the feather hydrolysates at the fourth day. Among various free amino acids detected, the relative higher contents of amino acids were sulfuric amino acid and branch-chain amino acid. Strain TCC-2 could also produce 134.6 mg/L IAA 12 hours after incubating in tryptophan-contained nutrient broth which is the reason the applied potential for stimulating roots growth of crop. The bacteria numbers of strain TCC-2 can reach to 10^8 CFU/mL by incubating in 6% sodium chloride medium that showed the salt-tolerant ability of strain TCC-2 and can be applied to mix with chemical fertilizers. Strain TCC-2 incubated in medium contained 1% feather, 0.5% rock phosphate and 0.5% plant ash (F+R+A medium), at the fourth day it found that the feather structure was totally degraded by TCC-2 and the EC and soluble nitrogen contents in the feather hydrolysates were significantly increased. The bacteria numbers of TCC-2 was reached to 10^9 CFU/mL in the feather hydrolysates (F+R+A) in which soluble phosphate ion was detected to testify it from the medium source of calcium phosphate and rock phosphate. Applying the feather hydrolysates (F+R+A) with rapeseed meal (amounts equal to 120 kg-N/ha) in organic lettuce farmland could also increase the lettuce yield.

Key words: *Arthrobacter enclensis*, feather degradation, phosphate solubilization, indole-3-acetic acid, organic lettuce

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