

飼糧中添加纖維素酶對豬生長性能及 纖維消化率之影響⁽¹⁾

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摘 要

以飼養試驗及代謝試驗來探討肉豬飼糧中添加纖維素酶對肉豬生長性能及纖維等消化率之影響。在飼養試驗，生長肉豬（30 kg）及肥育肉豬（50 kg）各 48 頭，公母各半，採個飼，逢機分配三個處理組：對照組及添加纖維素酶 A（1 ml/kg）或 B（0.5 g/kg）處理組。纖維素酶 A 之活性為濾紙分解活性（FPA）18.5 unit/ml，羥甲基纖維素酶活性（CMCase）60 unit/ml 及木聚糖酶（Xylanase）1016 unit/ml；纖維素酶 B 之活性為 FPA 37.0 unit/g，CMCase 148 unit/g 及 Xylanase 3600 unit/g，生長期飼糧以玉米—大豆粕為主，而肥育期飼糧以玉米—大豆粕—大麥為主。代謝試驗在生長期及肥育期各利用 24 頭閹公豬，飼糧處理組如飼養試驗，分別收集豬隻糞便以測定纖維等之消化率。試驗結果顯示，豬隻於生長期及肥育期飼糧中添加纖維素酶均可減少每增重 1 kg 所需的飼料量（ $P < 0.05$ ）；而添加纖維素酶 B 可顯著提高豬之增重（ $P < 0.05$ ），但與纖維素酶 A 組並無顯著差異。飼糧中添加纖維素酶 A 或 B 均可顯著提高生長豬及肥育豬之粗纖維、中洗纖維、酸洗纖維及半纖維素的消化率（ $P < 0.05$ ），亦可提高肥育豬之鈣消化率，但並不顯著影響能量消化率；而添加纖維素酶 A 亦可提高肥育豬之氮消化率（ $P < 0.05$ ）。本試驗結果顯示添加纖維素酶可改善肉豬飼料效率及纖維消化率，降低纖維排泄量。

關鍵詞：纖維素酶、纖維、消化率、生長性能、豬。

緒 言

提高豬對飼料組成分的消化率是降低豬排泄物量的直接方法。豬對飼料粗纖維的消化率約 45~55%（顏及戈，1981），低於其他有機物的消化率。纖維含量亦影響其他成分如蛋白質、能量及胺基酸的消化率（Hsu *et al.*, 1983; Taverner and Farrell, 1981），飼料中添加酵素（酶）或微生物可提高飼料中營養分的消化與利用（徐，1972；1976；陳等，1997；Campbell and Bedford, 1992；施及徐，1997）。添加酵素於飼料之目的在於分解飼料中蛋白質、植物細胞壁、非澱粉之多醣類等，增加酵素與基質接觸的面積，以提高消化率。

添加纖維素酶於剛離乳仔豬可降低離乳後下痢的發生及生長停滯（Rotter, 1990），添加 β -glucanase 可提高生長豬對大麥為主飼糧之消化率而改善飼料效率（Graham *et al.*, 1989）。豬飼料添加纖維素酶對肉豬生長性能及消化纖維等之效果值得探討，以求降低豬糞排泄量。

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材料與方法

I. 纖維素酶活性測定

兩種纖維素酶 A（液狀，由台灣糖業研究所提供）、B（粉狀，市售進口商品）之酵素活性測定結果（表 1），纖維素酶活性表示以濾紙分解活性（Filter paper activity, FPA; Mohagheghi *et al.*, 1988）及羧甲基纖維素酶活性（Carboxymethyl cellulase, CMCase; Sami *et al.*, 1988）均以每分鐘產生 1 μ mole 之還原糖為 1 活性單位，纖維素酶 A 之活性為 FPA 18.5 unit/ml，CMCase 60 unit/ml 及 xylanase 1016 unit/ml；纖維素酶 B 之活性為 FPA 37.0 unit/g，CMCase 148 unit/g 及 xylanase 3600 unit/g，就 FPA 而言纖維素酶 A 的活性約為商用纖維素酶 B 的一半，由纖維素酶分析活性及商用產品推薦量作為試驗添加量。

表 1. 纖維素酶之活性分析

Table 1. The activities of cellulase used as feed supplements

Cellulase	The activities of enzymes		
	FPA ¹	CMCase ²	Xylanase ³
A (Taiwan Sugar Research Institute), unit/ml	18.5	60	1016
B (Biofeed plus), unit/g	37.0	148	3600

¹ FPA (Filter Paper Activity): 50°C, 0.05 M citrate buffer, pH 4.8, 60 min, substrate 1×6 cm filter paper.

² CMCase (endoglucanase): 50°C, 0.05 M citrate buffer, pH 4.8; 30 min, substrate 2% CMC.

³ Xylanase: 50°C, 0.05 M citrate buffer, pH 4.8, 30 min, substrate 1% xylan.

II. 飼養試驗

- (i) 生長期：三品種雜交（LYD）肉豬 48 頭，公母各半，體重約 30 kg，分置於 48 欄，依性別逢機分別飼予處理飼糧，其營養分均超過豬營養需要量（NRC, 1988），飼糧均含粗蛋白質 16% 之玉米—大豆粕飼糧（表 2），其飼糧處理分別為 1. 對照組；2. 添加纖維素酶 A（1 ml/kg）；3. 添加纖維素酶 B（0.5 g/kg），肉豬飼養至體重約 50 kg，飼糧與飲水均任飼。
- (ii) 肥育期：以肉豬 48 頭，體重約 50 kg，公母各半，分置於 48 欄，依性別逢機分別飼予 3 種飼糧，飼糧中含 25% 大麥，使飼糧均含粗蛋白質 14% 之玉米—大麥—大豆粕飼糧（表 2），其飼糧處理為 1. 對照組；2. 添加纖維素 A（1 ml/kg）；3. 添加纖維素酶 B（0.5 g/kg），飼養至體重約 100 kg。上述生長期及肥育期測定項目為隻日增重，採食量及飼料/增重。

III. 代謝試驗

選取生長豬體重約 30 kg 及肥育豬體重約 50 kg 之閹公豬各 24 頭，各分二批次分別進行代謝試驗，每批次 12 頭豬分別飼予上述如生長期及肥育期之飼養試驗處理飼糧，豬經適應於代謝架 7 天後，各收集糞 5 天，以測定粗纖維、粗灰分、有機質、鈣、磷（AOAC, 1984）、中洗纖維（neutral detergent fiber, NDF）及酸洗纖維（acid detergent fiber, ADF）（Goering and Van Soest, 1970）等成分，而半纖維素（Hemicellulose）= NDF - ADF，並計算其排泄量。飼糧中添加 0.5% 三氧化二鉻（Cr₂O₃）為收集糞之標識物，每日 8:00 及 15:00 各飼一次，以 $90 \times W^{0.75}$ 換算飼料量，所收集糞便，經乾燥粉碎，以備用。

表 2. 基礎飼糧之組成 (%)

Table 2. The composition of basal diets for pig, %

Item	Grower	Finisher
Ingredients		
Ground corn	73.50	56.00
Barley	—	25.00
Soybean meal (43.5% CP)	24.00	16.50
Dicalcium phosphate	1.30	1.10
Limestone, pulverized	0.40	0.70
Salt	0.40	0.40
Vitamin premix ^a	0.10	0.10
Trace mineral premix ^b	0.15	0.15
L-Lysine-HCl, 78%	0.05	—
Choline chloride, 50%	0.10	0.05
Calculated value		
Crude protein, %	16.00	14.00
Digestible energy, kcal/kg	3400	3300
Calcium, %	0.75	0.60
Available phosphorus, %	0.40	0.30
Crude fiber, %	3.00	3.40
Analyzed value		
Crude protein, %	15.80	14.50
Calcium, %	0.78	0.65
Total phosphorus, %	0.68	0.61
Crude fiber, %	2.84	3.61
Neutral detergent fiber, %	11.76	17.70
Acid detergent fiber, %	3.84	4.43
Hemicellulose, %	7.92	13.27

^a Supplied the following per kilogram of diet: Vitamin A, 6000 IU; Vitamin D₃, 800 IU; Vitamin E, 20 IU; Vitamin K, 4 mg; Vitamin B₂, 4 mg; Vitamin B₆, 1 mg; Vitamin B₁₂, 20 µg; Niacin, 30 mg; Pantothenate, 16 mg; Biotin, 0.1 mg; Folic acid 0.5 mg.

^b Supplied per kilogram of diet : Fe, 140 mg ; Mn, 20 mg; Zn, 120 mg; I, 0.45 mg; Cu, 7 mg.

IV. 統計分析

試驗所得之資料，利用統計分析系統 (Statistical Analysis System; SAS, 1988)，以一般線性模式程序 (General Linear Model Procedure; GLM) 進行變方分析，並以鄧肯氏新多次變域測定法 (Duncan's New Multiple Range Test) 比較處理間差異的顯著性 (Steel and Torrie, 1980)。

結果與討論

I. 飼養試驗

飼糧中添加纖維素酶對生長豬及肥育豬生長性能之影響結果 (如表 3 及表 4)，顯示纖維素酶可顯著改善生長豬及肥育豬之每增重 1 kg 所需的飼料量 ($P < 0.05$)；而飼餵含酵素 B 組之豬隻

之日增重顯著優於對照組 ($P < 0.05$)，但與酵素 A 組豬之增重並無顯著差異。採食纖維素酶 A 或 B 之飼料與對照組比較，在生長期其增重分別增加 8 及 16%，飼料／增重則分別改善 3 及 6%，在肥育期則增重分別增加 10 及 16%，飼料／增重則分別改善 6.5% 及 8%。

表 3. 飼糧中添加纖維素酶對生長豬生長性能之影響

Table 3. Effect of cellulase supplementation in corn-soybean meal diet on the growth performance of growing pigs

Item	Control	Cellulase ^x		SE
		A	B	
Daily feed intake, kg	1.58	1.66	1.73	0.51
Daily gain, kg	0.63 ^b	0.68 ^{ab}	0.73 ^a	0.06
Feed/gain	2.51 ^a	2.44 ^b	2.37 ^b	0.35

^x Supplied per kg of diet: cellulase A, 1 ml (Taiwan Sugar Research Institute); cellulase B, 0.5g (Biofeed plus).

^{a,b} Data with different superscripts in the same row differ significantly ($P < 0.05$).

表 4. 飼糧中添加纖維素酶對肥育豬生長性能之影響

Table 4. Effect of cellulase supplementation in corn-barley-soybean meal diet on the growth performance of finishing pigs

Item	Control	Cellulase ^x		SE
		A	B	
Daily feed intake, kg	2.24	2.31	2.40	0.80
Daily gain, kg	0.67 ^b	0.74 ^{ab}	0.78 ^a	0.07
Feed/gain	3.34 ^a	3.12 ^b	3.08 ^b	0.45

^{x,a,b} Same as Table 3.

本試驗之生長豬及肥育豬飼糧含粗纖維分別為 2.8% 及 3.69% (表 2)，豬隻飼糧中粗纖維含量越高，其生長性能越差 (King and Taverner, 1975)，陳等 (1997) 報告肥育豬飼糧含 3% 及 4% 粗纖維之飼糧添加 β -甘露聚糖酶 (β -mannanase) 之豬隻日增重，分別較對照組 (3% 粗纖維) 高出 4.2% 及 6.9%；飼料效率分別改進 6.3 及 6.5%。對於飼糧中所含之非澱粉多醣類 (Non-starch polysaccharides, NSP) 包括 β -葡萄糖聚糖、五碳聚糖、果膠、纖維素及半纖維素等，而多種纖維素酶包括 β -葡萄糖聚糖酶、五碳聚糖酶、纖維素酶、半纖維素酶等可分解上述特定之物質或提高胃腸道中某類酵素的活性，進而改善飼糧的營養價值 (Kornegay, 1978, 1981; Graham *et al.*, 1986; Graham *et al.*, 1989; Bedford *et al.*, 1992)。纖維素酶及半纖維素酶可將粗纖維分解釋出細胞質，除了能刺激膽汁分泌及胰腺分泌消化酶之外 (Jacobs, 1983; Ikegami *et al.*, 1990)，尚能促進胰腺泡的生長，對其他消化器官的發育亦有增進的效果 (Ikegami *et al.*, 1990; Jacobs, 1983)。本試驗之肥育豬飼糧中以大麥取代 1/3 玉米，再添加纖維素酶，則可使大麥中非澱粉多醣類進行水解作用，使腸內容物的粘稠度降低，而提高大麥對豬的營養價值，可顯著改善豬隻增重及飼料效率 (Graham *et al.*, 1986; Graham *et al.*, 1989)。

II. 代謝試驗

飼糧中添加纖維素酶 A 或 B 均可提高生長豬 (表 5) 及肥育豬 (表 6) 之粗纖維、中洗纖維及

酸洗纖維及半纖維素的消化率 ($P < 0.05$)，而纖維素酶 B 及 A 分別顯著降低生長期豬隻之中洗纖維及酸洗纖維排泄量 ($P < 0.05$)。肥育期豬隻添加大麥取代部分玉米之飼糧再添加纖維素酶 A 或 B 均可降低豬排泄中洗纖維及酸洗纖維之量，顯示添加纖維素酶可有效分解豬隻飼糧中纖維質及醣類，有利於降低中洗纖維及酸洗纖維之排泄量。

表 5. 飼糧中添加纖維素酶對生長豬之粗纖維、中洗纖維及酸洗纖維排泄之影響

Table 5. Effect of cellulase supplementation in corn-soybean diets on the digestibilities of crude fiber, neutral detergent fiber and acid detergent fiber in growing pigs

Item	Control	Cellulase ^x		SE
		A	B	
Crude fiber intake, g/day	48.54	51.99	52.67	5.20
Fecal crude fiber, g/day	19.03	19.68	19.02	0.83
Apparent crude fiber dig., %	58.79 ^b	62.15 ^a	63.89 ^a	2.15
NDF intake, g/day	210.20	233.30	233.70	81.50
Fecal NDF, g/day	78.60 ^a	74.20 ^{ab}	70.30 ^b	9.70
Apparent NDF dig., %	62.65 ^b	68.23 ^a	70.81 ^a	2.55
ADF intake, g/day	68.60	76.20	78.30	31.50
Fecal ADF, g/day	30.50 ^a	27.40 ^b	28.40 ^{ab}	3.50
Apparent ADF dig., %	55.54 ^b	64.20 ^a	63.02 ^a	3.80
Hemicellulose intake, g/day	141.60	157.10	155.40	18.00
Fecal Hemicellulose, g/day	48.10 ^a	46.80 ^{ab}	41.90 ^b	6.30
Apparent Hemicellulose dig., %	66.03 ^b	70.21 ^a	73.03 ^a	2.18

^{x,a,b} Same as Table 3.

表 6. 飼糧中添加纖維素酶對肥育豬之粗纖維、中洗纖維及酸洗纖維消化率及之影響

Table 6. Effect of cellulase supplementation in corn-barley-soybean diet on digestibilities of crude fiber, neutral detergent fiber and acid detergent fiber in finishing pigs

Item	Control	Cellulase ^x		SE
		A	B	
Crude fiber intake, g/day	73.07	73.25	72.74	3.15
Fecal crude fiber excretion, g/day	30.46 ^a	28.88 ^b	27.82 ^b	1.25
Apparent crude fiber dig., %	58.31 ^b	60.57 ^a	61.75 ^a	1.15
NDF intake, g/day	358.30	359.10	355.00	83.50
Fecal NDF, g/day	96.90 ^a	85.60 ^b	84.30 ^b	9.50
Apparent NDF dig., %	73.20 ^b	76.10 ^a	76.22 ^a	0.95
ADF intake, g/day	89.60	89.80	88.80	28.50
Fecal ADF, g/day	39.20 ^a	32.10 ^b	33.60 ^b	7.30
Apparent ADF dig., %	58.61 ^b	64.20 ^a	62.21 ^a	0.81
Hemicellulose intake, g/day	268.70	269.30	266.20	16.20
Fecal Hemicellulose, g/day	57.70 ^a	53.50 ^{ab}	50.70 ^b	5.30
Apparent Hemicellulose dig., %	78.52 ^b	80.13 ^a	80.95 ^a	1.04

^{x,a,b} Same as Table 3.

飼糧中添加纖維素酶並未能提高生長豬及肥育豬之熱能消化率，但添加纖維素酶 A 或 B 可改善肥育豬之氮及鈣之消化率（表 7 及表 8）。在多數研究報告認為提高飼料粗纖維含量，則飼料中粗纖維、中洗纖維及酸洗纖維、能量及鈣之消化率降低（Farrell, 1973; Kass *et al.*, 1980; Calvert *et al.*, 1985; 陳等, 1994），如適量添加纖維素酶則可提高中洗纖維及酸洗纖維之利用率及改善豬隻生長性狀。依 Graham *et al.* (1989) 指出肥育豬飼料添加 β -葡萄糖聚醣酶及木聚醣酶等消化多醣類之酵素，可以改善蛋白質、礦物質及其他營養分消化率的趨勢。陳等（1994）報告添加恒美酵素（半纖維素酶）於含 3% 粗纖維之肥育豬飼糧中，可提高酸洗纖維、能量及鈣消化率，可減少豬排糞便量。

表 7. 飼糧中添加纖維素酶對生長豬之熱能及氮之消化率及排泄量之影響

Table 7. Effects of cellulase supplementation in corn-soybean meal diet on the digestibilities of energy and nitrogen in growing pigs

Item	Control	Cellulase ^x		SE
		A	B	
Gross energy intake, kcal/day	6821	7521	7496	105
Fecal gross energy excretion, g/day	934	955	1004	45
Apparent energy dig., %	86.31	87.30	86.61	1.37
Total nitrogen intake, g/day	48.54	51.99	52.67	2.84
Fecal nitrogen excretion, g/day	6.82	6.70	6.68	0.32
Apparent nitrogen dig., %	85.94	87.11	87.31	0.89

^{x,a,b} Same as Table 3.

表 8. 飼糧中添加纖維素酶對肥育豬之熱能、氮及鈣消化率及排泄量之影響

Table 8. Effects of cellulase supplementation in corn-barley-soybean meal diets on digestibilities of energy, nitrogen and calcium in finishing pigs

Item	Control	Cellulase ^x		SE
		A	B	
Gross energy intake, kcal/day	7663	7750	7528	113
Fecal gross energy excretion, g/day	1156	1195	1208	43
Apparent energy dig., %	84.91	84.58	83.95	1.58
Total nitrogen intake, g/day	49.59	47.13	46.05	2.35
Fecal nitrogen excretion, g/day	8.50 ^a	7.28 ^b	7.76 ^{ab}	0.54
Apparent nitrogen dig., %	81.87 ^b	84.61 ^a	83.38 ^{ab}	0.50
Calcium intake, g/day	14.50	14.20	14.20	2.60
Fecal calcium excretion, g/day	5.52 ^b	4.50 ^a	4.60 ^a	0.80
Apparent calcium dig., %	62.06 ^b	68.31 ^a	67.61 ^a	0.15

^{x,a,b} Same as Table 3.

本試驗結果顯示在玉米—大豆粕為主之生長豬飼糧及玉米—大麥—大豆粕為主之肥育豬飼糧添加纖維素酶，可提高粗纖維、中洗纖維、酸洗纖維及半纖維素等消化率（ $P < 0.05$ ），可改善豬之飼料效率，降低中洗纖維及酸洗纖維排泄量（ $P < 0.05$ ）。

誌 謝

承台灣糖業研究所鄭文玲小姐提供纖維素酶及協助酵素活性測定，本系李世郎先生及化驗室同仁等協助試驗及分析等事宜，本試驗得以順利完成，謹此誌謝。

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Effects of Dietary Cellulase Supplementation on Growth Performance and Fiber Digestibility in Growing and Finishing Pigs⁽¹⁾

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Abstract

Three feeding and digestion trials were conducted to evaluate the effects of cellulase supplementation on growth performance and fiber digestibility in growing and finishing pigs. In feeding trials, 48 crossbred pigs for each trial were penned individually and allotted to three dietary treatments based on sex and weight. The treatments were the control and diets supplemented with cellulase A (1 ml/kg) or B (0.5 g/kg). The activities of enzymes were FPA 18.5 unit/ml, CMCase 60 unit/ml and xylanase 1016 unit/ml in cellulase A and FPA 37.0 unit/g, CMCase 14.8 unit/g and xylanase 3600 unit/g in cellulase B. The control diets were corn-soybean meal-based and corn-barley-soybean meal-based for grower and finisher, respectively. In digestion trials, 24 growers (30 kg) and 24 finishers (50 kg) were used for measuring the digestibilities of crude fiber, acid detergent fiber (ADF), neutral detergent fiber (NDF), and hemicellulose, etc.

The results showed that cellulase A or B supplementation decreased the feed/gain ($P < 0.05$) in growing and finishing pigs. Cellulase B improved daily gain ($P < 0.05$). There were no differences in growth or feed/gain between pigs fed diets with cellulase A and B. The digestibilities of crude fiber, ADF, NDF and hemicellulose in grower and finisher were improved by the cellulase supplementation ($P < 0.05$). Cellulases A and B also improved calcium digestibility in finishing pigs. Cellulase A improved digestibility of nitrogen in finisher ($P < 0.05$). These results suggested that cellulase supplementation could improve feed efficiency and

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digestibilities of fibers, and would decrease the fiber excretion in growing and finishing pigs.

Key words : Cellulase, Fiber, Digestibility, Growth performance, Pig.