ENZYMES FOR USE IN HIGH DDGS SWINE DIETS

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Introduction

- Energy is the most expensive component of swine diets
- Use of corn for ethanol production in 2009
  - 3.8 billion bushels (30% of total use)
    - Reduced availability of supply for feed
    - Increased corn price
  - Resulted in production of 30.5 MMT of DDGS
    - High energy value for swine
    - Generally an economical partial replacement for corn and soybean meal

Concentration of Energy in Corn and 10 sources of Corn DDGS Fed to Growing Pigs[1]

	Corn	DDGS Average	DDGS SD	DDGS Lowest Value	DDGS Highest Value
GE, kcal/kg DM	4,496	5,434	108	5,272	5,592
ATTD[2] of energy, %	90.4	76.8	2.73	73.9	82.8
DE, kcal/kg DM	4,088	4,140	205	3,947	4,593
ME, kcal/kg DM	3,989	3,897	210	3,674	4,336

[1] Data from Pedersen et al. (2007) (Adapted from Stein and Shurson, 2009)
[2] ATTD = apparent total tract digestibility.

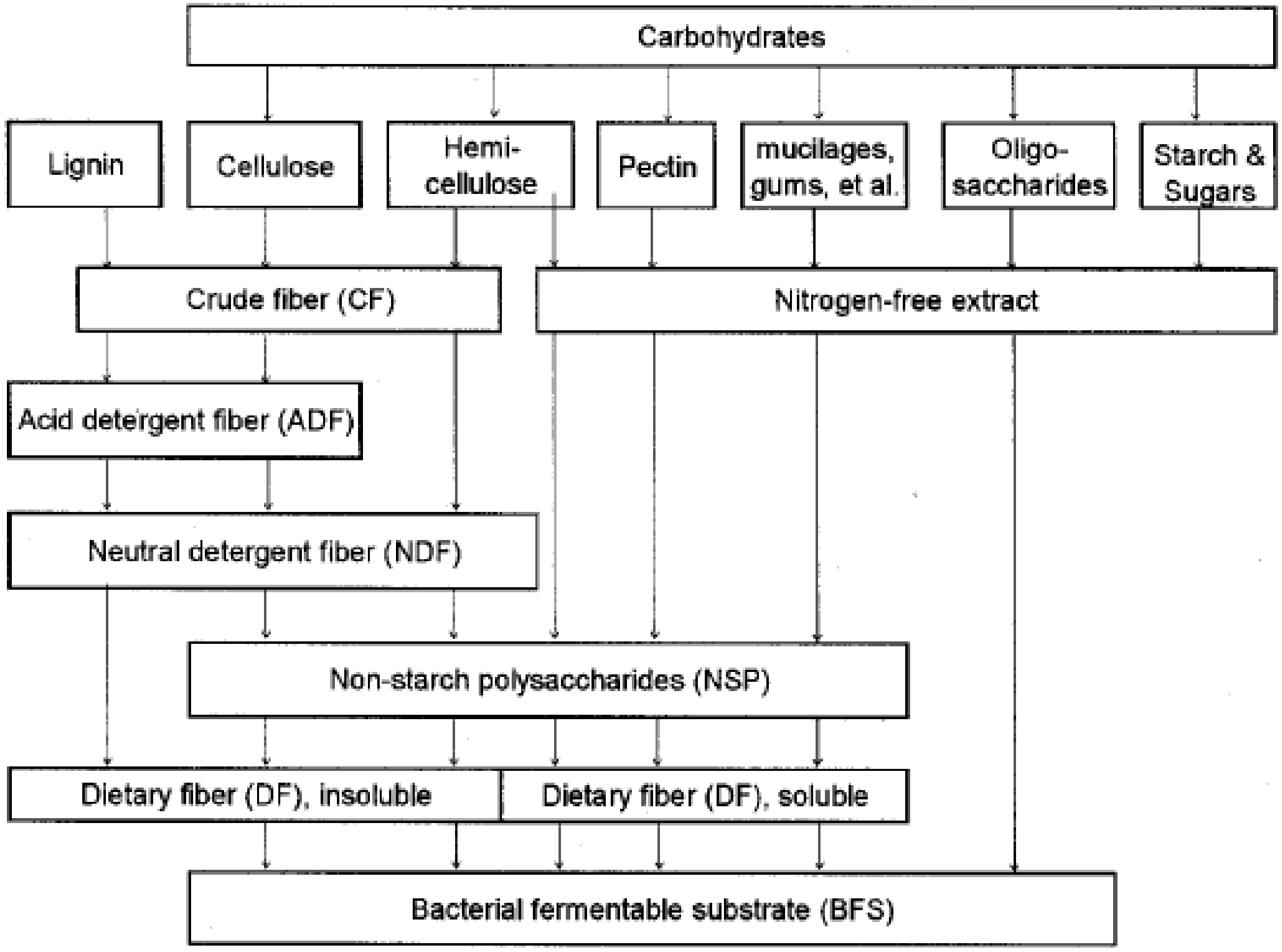
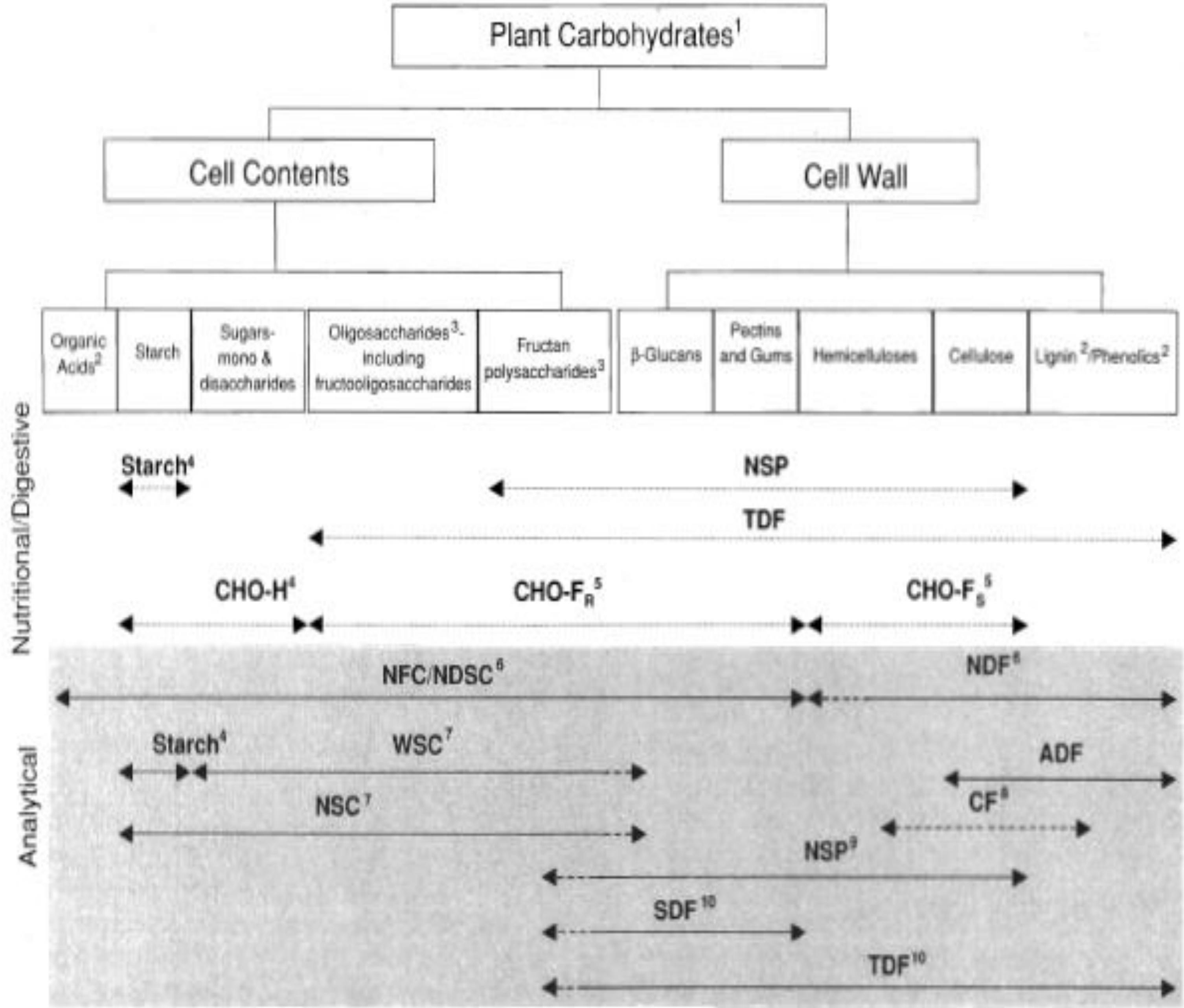


Figure 1.2. Classification of the carbohydrates (adapted from Bakker et al. (1998))



Plant Carbohydrates[1]
Cell Contents
Cell Wall
Organic Acids[2]
Starch
Sugars-mono & disaccharides
Oligosaccharides[3]-including fructooligosaccharides
Fructan polysaccharides[3]
β-Glucans
Pectins and Gums
Hemicelluloses
Cellulose
Lignin[2]/Phenolics[2]
Nutritional/Digestive
Starch[4]
NSP
TDF
CHO-H[4]
CHO-F$_R$[5]
CHO-F$_S$[5]
Analytical
NFC/NDSC[6]
NDF[6]
Starch[4]
WSC[7]
ADF
NSC[7]
CF[8]
NSP[9]
SDF[10]
TDF[10]

Concentration of Carbohydrates and ATTD of Dietary Fiber in Corn DDGS[1]

	Average	Low Value	High Value	SD
Starch, total, %	7.3	3.8	11.4	1.4
Starch, soluble, %	2.6	0.5	5.0	1.2
Starch, insoluble, %	4.7	2.0	7.6	1.5
ADF, %	9.9	7.2	17.3	1.2
NDF, %	25.3	20.1	32.9	4.8
Insoluble TDF, %	35.3	26.4	38.8	4.0
Soluble TDF, %	6.0	2.36	8.54	2.1
TDF, %	42.1	31.2	46.3	4.9
ATTD[2] of TDF, %	43.7	23.4	55.0	10.2

[1] N = 46 for data on starch, ADF, and NDF; n = 8 for data on insoluble, soluble, and total dietary fiber.

[2] ATTD = apparent total tract digestibility.

Stein and Shurson (2009)

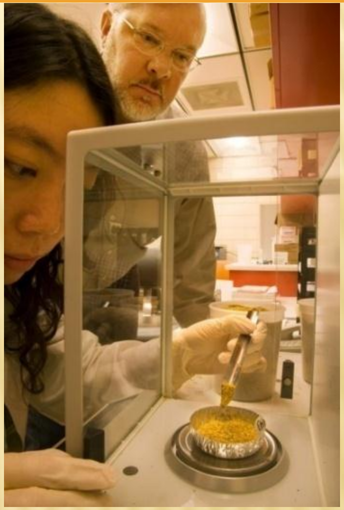
Analytical Variation (%) in NDF Content Among Laboratories (as-is basis)

	ARS IA	Eurofins DSM	ESCL MO	MVTL MN
Canola meal	23.3	21.7	23.0	20.8
Corn	8.7	7.5	17.2	7.3
DDGS	31.0	25.5	37.4	26.4
Poultry meal	25.1	18.2	32.5	18.5
Soybean hulls	63.0	62.1	64.0	62.7
Soybean meal	7.6	8.1	7.5	6.2
Wheat	13.2	7.9	13.0	9.9
Wheat midds	36.1	35.1	40.6	35.5

Analytical Variation (%) in Crude Fat Content Among Laboratories (as-is basis)

	ARS IA	MN	ILL	Eurofins DSM	ESCL MO	MVTL MN
Canola meal	2.93	3.39	2.38	3.33	3.26	4.00
Corn	2.77	3.14	2.96	3.75	2.51	3.61
DDGS	9.04	12.69	8.64	12.39	10.26	11.26
Poultry meal	13.44	13.76	12.85	12.85	11.52	12.79
Soybean hulls	1.16	1.14	0.94	1.01	0.71	1.33
Soybean meal	1.03	1.46	1.11	1.14	1.03	1.48
Wheat	1.39	1.31	0.75	1.22	1.00	1.53
Wheat midds	3.02	3.66	2.73	3.83	2.62	3.87

Sources of Analytical Variation



- Sampling of the material to be analyzed
- Preparation of samples for analysis
- Methodological differences
- Technique differences among analysts
- Environment, reagent, equipment, and calibration differences among laboratories
- Errors in application or operation of methods
- Errors in calculating results

NSP Composition of DDGS and Potential Application of Enzymes

Concentrations of Starch (+ Sugars), NSP, Protein, and Fat (% as-is) of Selected Feed Ingredients[1]

Ingredient	Starch	NSP	Protein	Fat
Wheat middlings	25	37	16	4
Oats	39	31	11	5
Corn DDGS[2]	4	24	28	10
Barley	54	18	11	2
Soybean meal	14	17	47	2
Field peas	47	14	23	1
Wheat	61	10	12	2
Corn	63	10	9	4

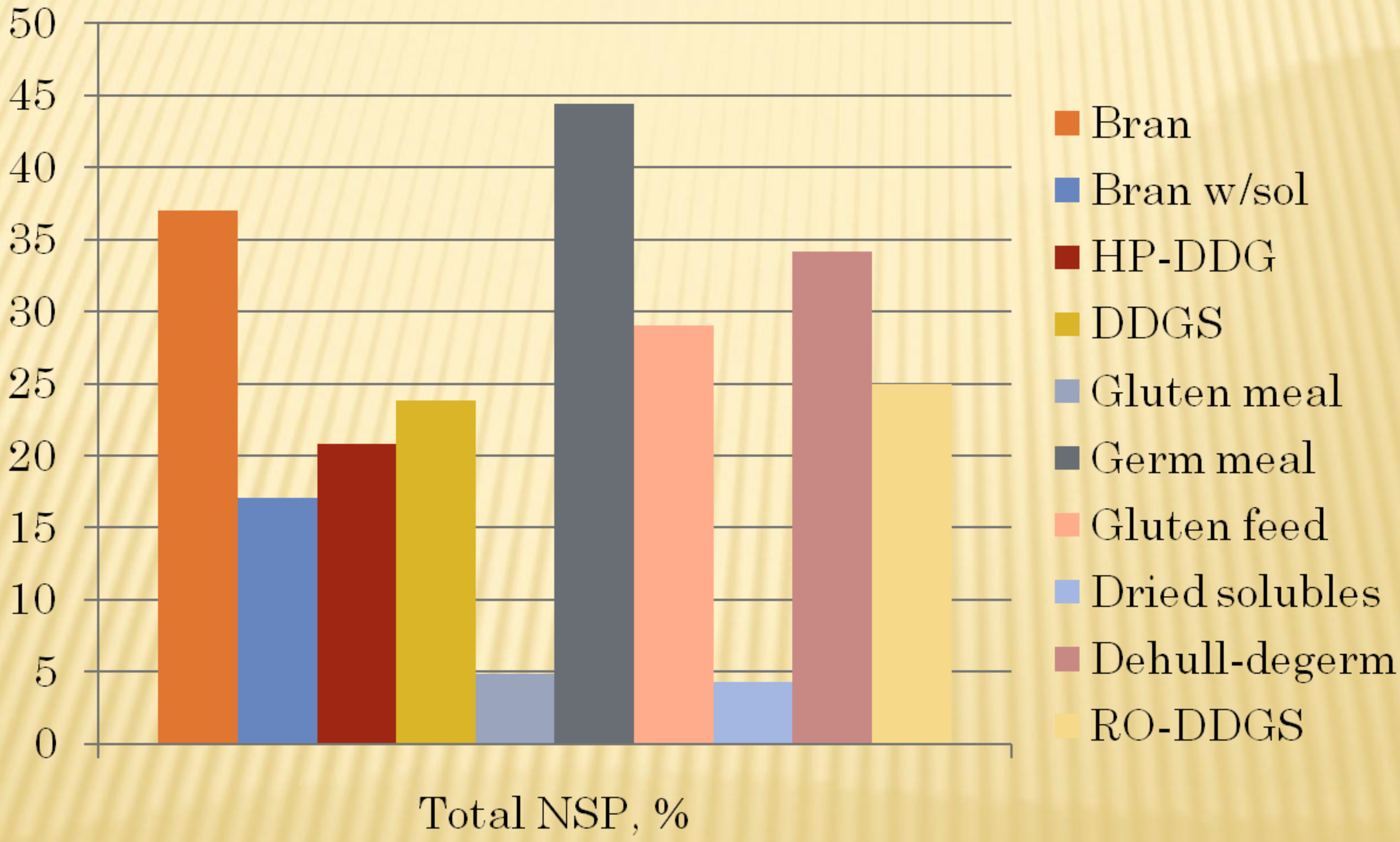
[1] Adapted from CVB, 1994.
[2] Anderson et al. (2010)

Major Components (%) of Corn Fiber

	A	B	C	D	E	F	Avg.
Starch	22	11	18	22	20	23	19
Hemicellulose	**40**	**53**	**32**	**47**	**29**	**39**	**40**
Xylose	24	25	20	28	18	19	22
Arabinose	16	18	10	19	11	11	14
Cellulose	12	18	24	nd	14	nd	17
Protein	12	11	nd	nd	11	12	12

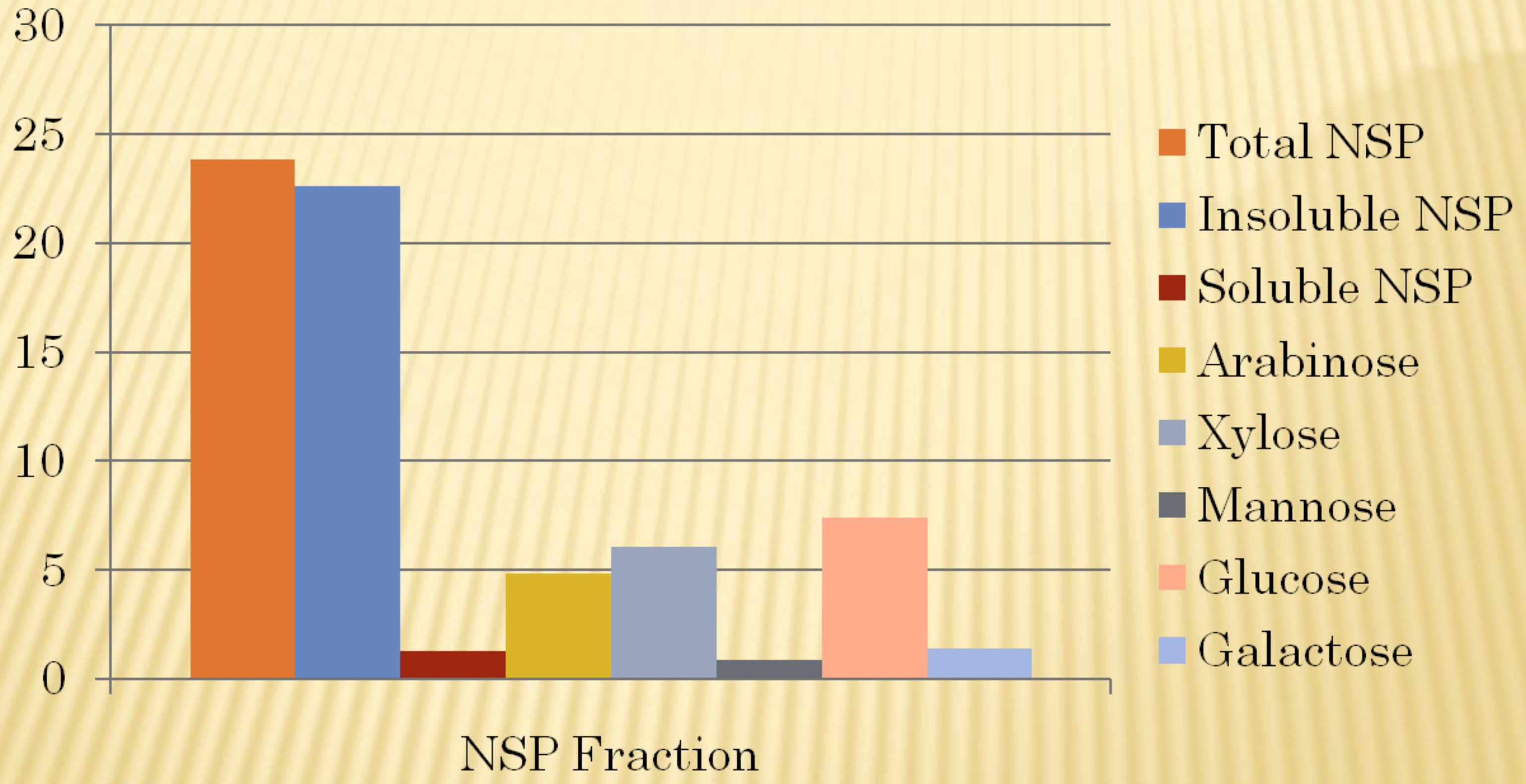
Compilation of 6 studies representing different geographic regions (Leathers,1998)

Total NSP of Corn Co-products (as-is basis, %)



Patience and Kerr, 2010 (unpublished)

NSP Composition of DDGS (as-is basis, %)

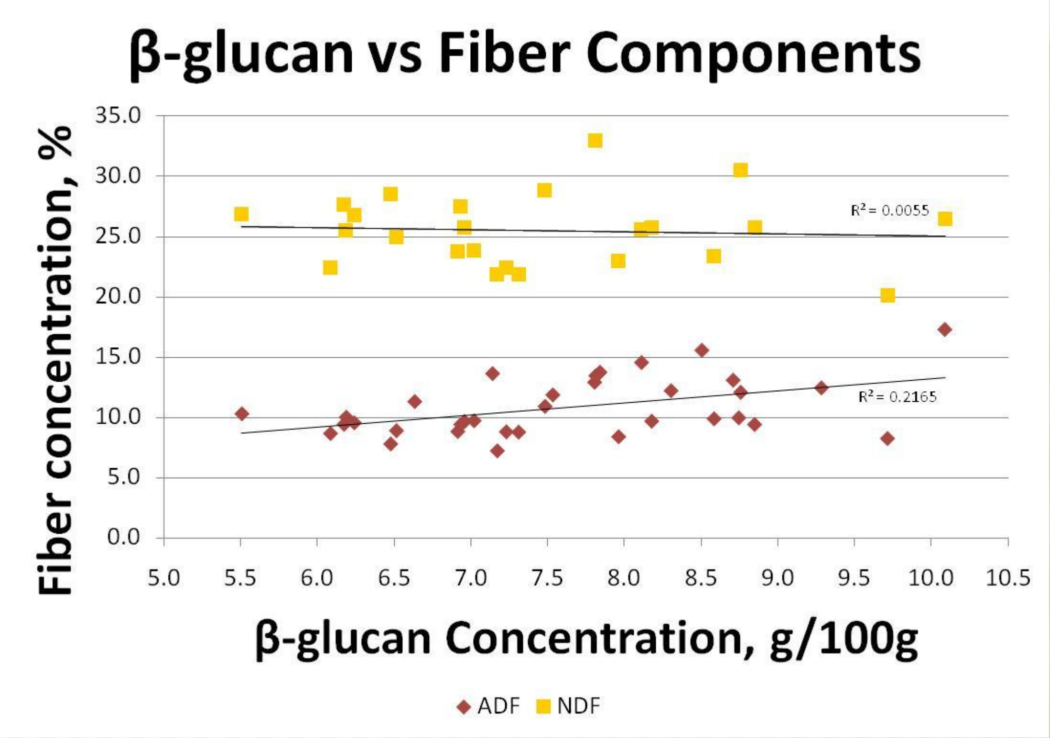


Rhamnose, ribose, and fucose analysis resulted in high lab error and data are not presented.

Patience and Kerr, 2010 (unpublished)

β-glucan Content of DDGS and Correlation with ADF and NDF

Summary Statistics			
	BG, %	ADF, %	NDF, %
Mean	7.61	10.68	25.35
Standard Deviation	1.11	2.33	3.08
Coefficient of Variation	14.54	21.78	12.15



Pomerenke et al. (2010)

Enzymes

- Studied for many years to improve nutrient digestibility in plant-based ingredients for swine and poultry.
  - Initial focus on phytase
  - More recently focus on NSPases
- Enzymes must match the target substrates
- Applications:
  - Formulate diets to a typical nutrient content
    - supplement with an enzyme to hopefully see an improvement in feed conversion
  - Formulate diets with reduced nutrient content
    - to hopefully get enough contribution from the enzyme to restore nutrient levels to meet requirements while reducing costs.

Objective

- Determine the effectiveness of 10 commercially available enzyme/feed additives for:
  - improving energy and nutrient digestibility
  - improving growth performance
  - diets containing 30% DDGS
  - nursery and finishing pigs

Materials and Methods

- 10 feed additives were evaluated
  - Based on:
    - Potential to improve energy and fiber digestibility
    - Potential to modulate the microbial ecology of the GIT
  - Added at manufacturer's recommended rates
  - Assumed active ingredients and activity level on product label
- 30% DDGS nursery and finisher diets
  - Adequate for all nutrients (NRC, 1998)
  - Indigestible marker - titanium oxide (0.5%)
    - Apparent nutrient digestibility determined by indirect method

Characterization of Exogenous Feed Additives Evaluated

Trade name	Manufacture	Lot # Date	Activity identification	Stated Activity
Allzyme SSF	Alltech, Lexington, KY	215612/460369 2/2/2008	Not provided (NP)	NP
Bactocell	Lallemand Animal Nutrition, Milwaukee, WI	8022202 3/3/2008	Pediococcus acidilactici	10×10^9 CFU/g
BioPlus 2B	Chr. Hansen, Milwaukee, WI	2821721 1/31/2008	Bacillus licheniformis and Bacillus subtilus	2.2×10^9 CFU/g
Econase XT25	AB Enzymes, Darmstadt, Germany	7855 12/19/2007	Endo-1,4-β-xylanase	160,000 U/g
Hemicel	ChemGen Corp., Gaithersburg, MD	NP NP	Hemicellulase	1.4×10^6 U/g
Porzyme 9302	Danisco Animal Nutrition, Marlborough, UK	4320849505 8/11/2008	Xylanase	8,000 U/g
Releez-a-zyme 4M*	Prince Agri Products Inc., Quincy, IL	31-2047 5/6/2008	β-glucanase Protease	440 U/g 11 U/g
Rovabio AP10%	Adisseo, Antony, France	NP NP	Endo-1,4-β-xylanase Endo-1,3(4)- β-glucanase	2,200 U/g 200 U/g
Roxazyme G2 G	DSM Nutritional Products Inc., Parsippany, NJ	NP NP	Endo-1,4-β-glucanase Endo-1,3(4)- β-glucanase Endo-1,4-β-xylanase	8,000 U/g 18,000 U/g 26,000 U/g
XPC yeast	Diamond V Mills Inc., Cedar Rapids, IA	300308 NP	*Saccharomyces cerevisiae* yeast culture	NP

* This product is no longer being marketed

Composition of Starter Diets (As-is basis)	
Ingredient	%
Corn	41.69
Soybean meal	16.94
Dried distillers grains with solubles	30.00
Whey, dried	5.00
Fish meal	2.50
Soybean oil	0.52
Dicalcium phosphate (21%P)	0.34
Limestone	0.96
Sodium chloride	0.35
Vitamin mix	0.30
Trace mineral mix	0.11
L-lysine-HCl	0.27
L-tryptophan	0.02
Dehulled, degermed corn	0.45
Tylosin premix	0.05
Titanium dioxide	0.50
TOTAL	100.00

Composition of Finisher Diets (As-is basis)	
Ingredient	%
Corn	61.98
Soybean meal	4.85
Dried distillers grains with solubles	30.00
Limestone	1.11
Sodium chloride	0.35
Vitamin mix	0.25
Trace mineral mix	0.10
L-lysine-HCl	0.33
L-tryptophan	0.03
Dehulled, degermed corn	0.475
Tylosin premix	0.025
Titanium dioxide	0.50
TOTAL	100.00

Materials and Methods

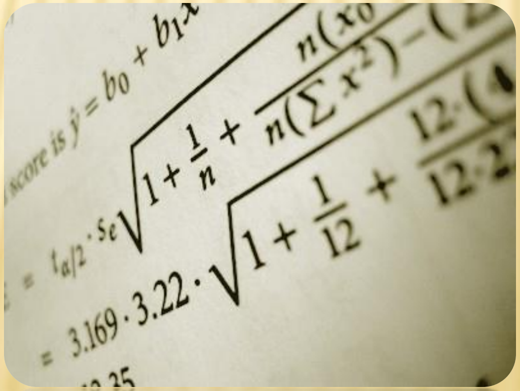
- Pigs
  - Nursery – 3 groups of 64 pigs (12 kg initial BW) = 192 pigs
  - Finisher – 2 groups of 48 pigs (98 kg initial BW) = 96 pigs
- Housed in individual stainless steel pens
- Dietary treatments randomly assigned to pens
  - Gender and BW maintained as equal as possible within and among groups
- Fed respective diets for 5 wks
  - Fed in meal form
  - *Ad libitum* access to feed and water
- Fecal samples collected at the end of wk-1, wk-3, and wk-5

Materials and Methods

- Laboratory analysis
  - Diets and feces dried in a 70°C forced air oven and ground through a 1 mm screen
  - C, N, and S – thermocombustion
  - ADF and NDF – Ankom 2000
  - Ether extract – petroleum ether
  - GE – isoperibol bomb calorimeter
  - P – ICP spectrometry

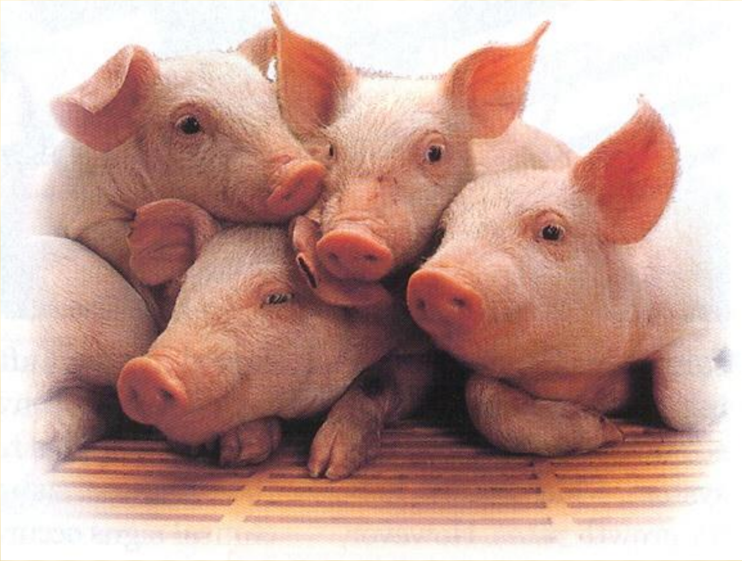
Materials and Methods

- Statistical analysis – Proc GLM
  - Pig was the experimental unit
  - Model included group, room, gender, week, and diet
  - No week x diet interactions
  - Only main effects are presented (LS means)

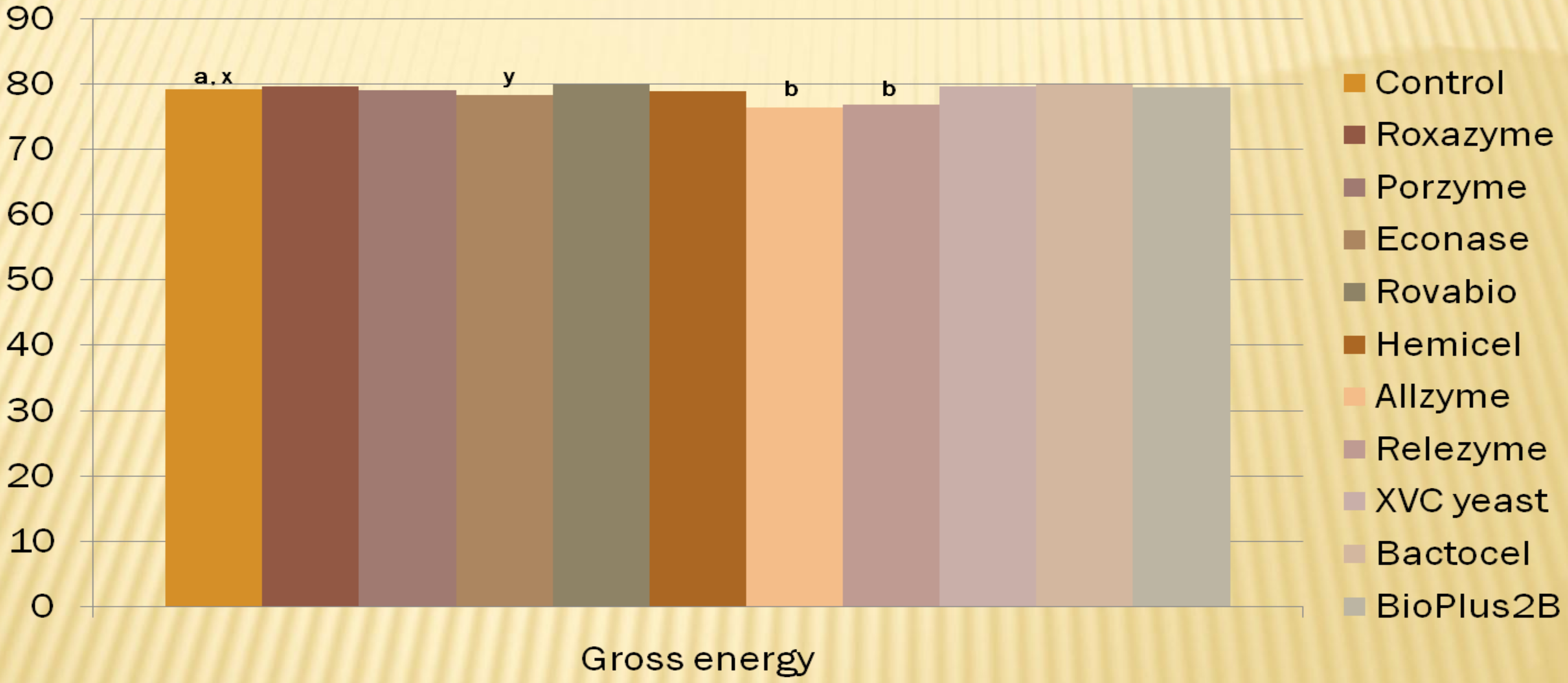


Results

- Starter Pigs (12 – 33 kg BW)
- 30% DDGS Diets with Feed Additives



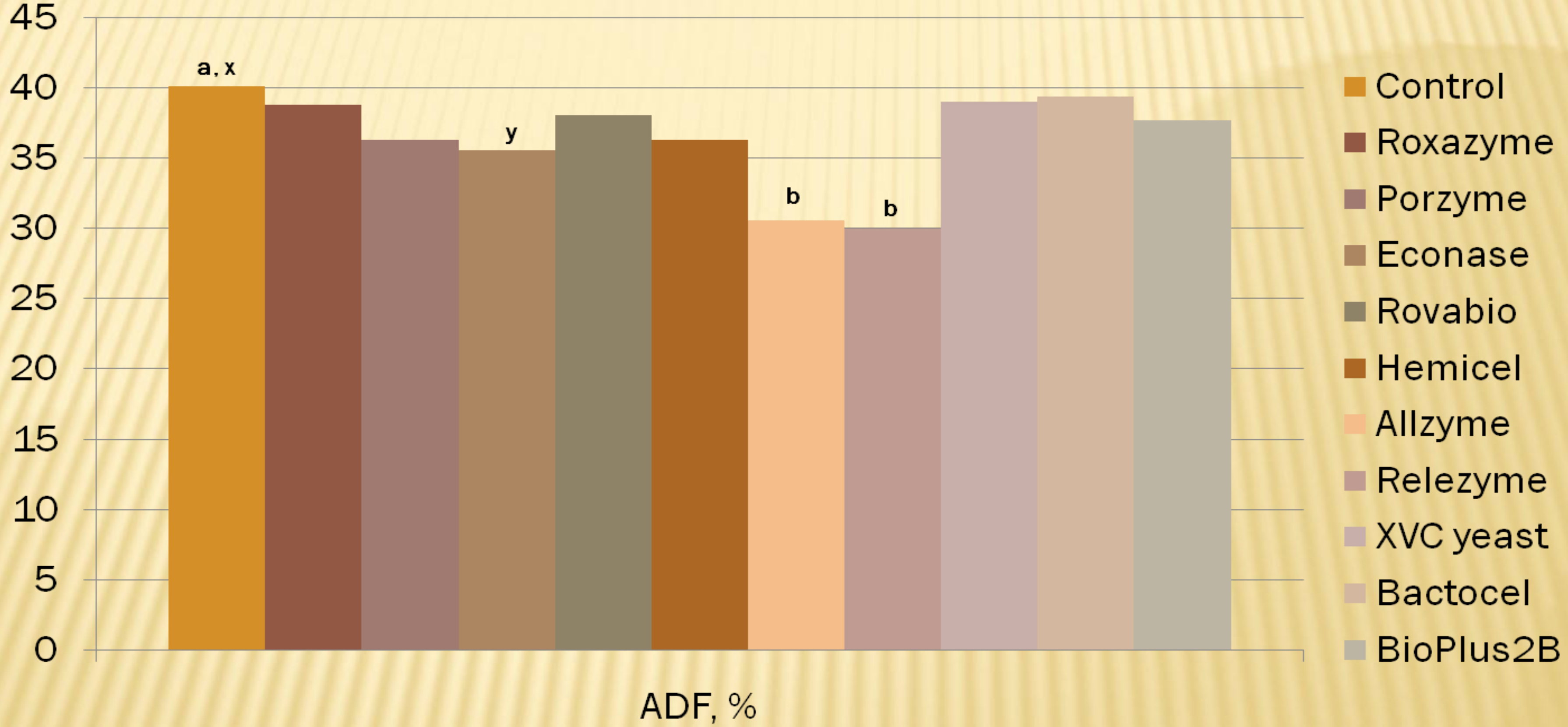
Apparent GE Digestibility (%)



[a, b] Control > Allzyme and Releez-a-zyme ($P < 0.01$)

[x, y] Control > Econase ($P < 0.10$)

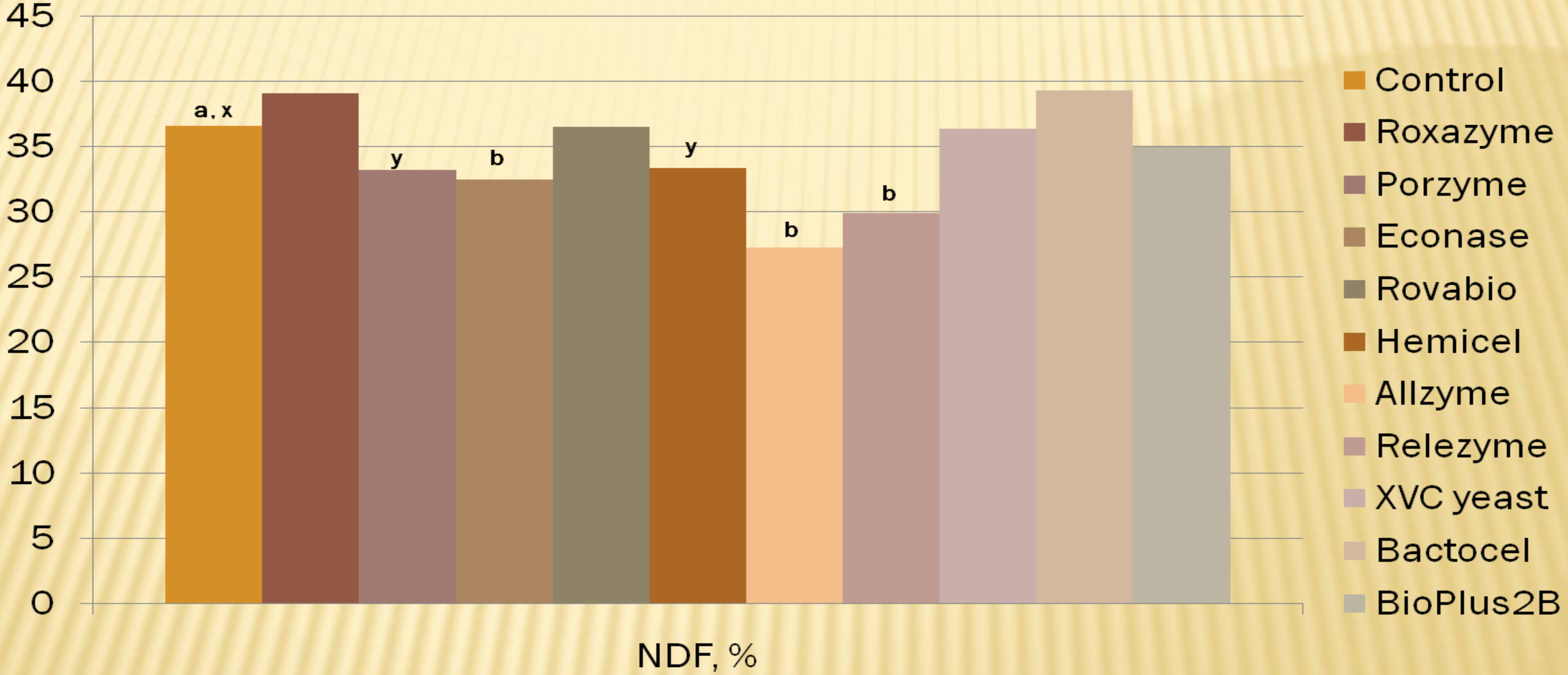
Apparent ADF Digestibility (%)



[a, b] Control > Allzyme and Releez-a-zyme ($P < 0.01$).

[x, y] Control > Econase ($P < 0.10$).

Apparent NDF Digestibility (%)



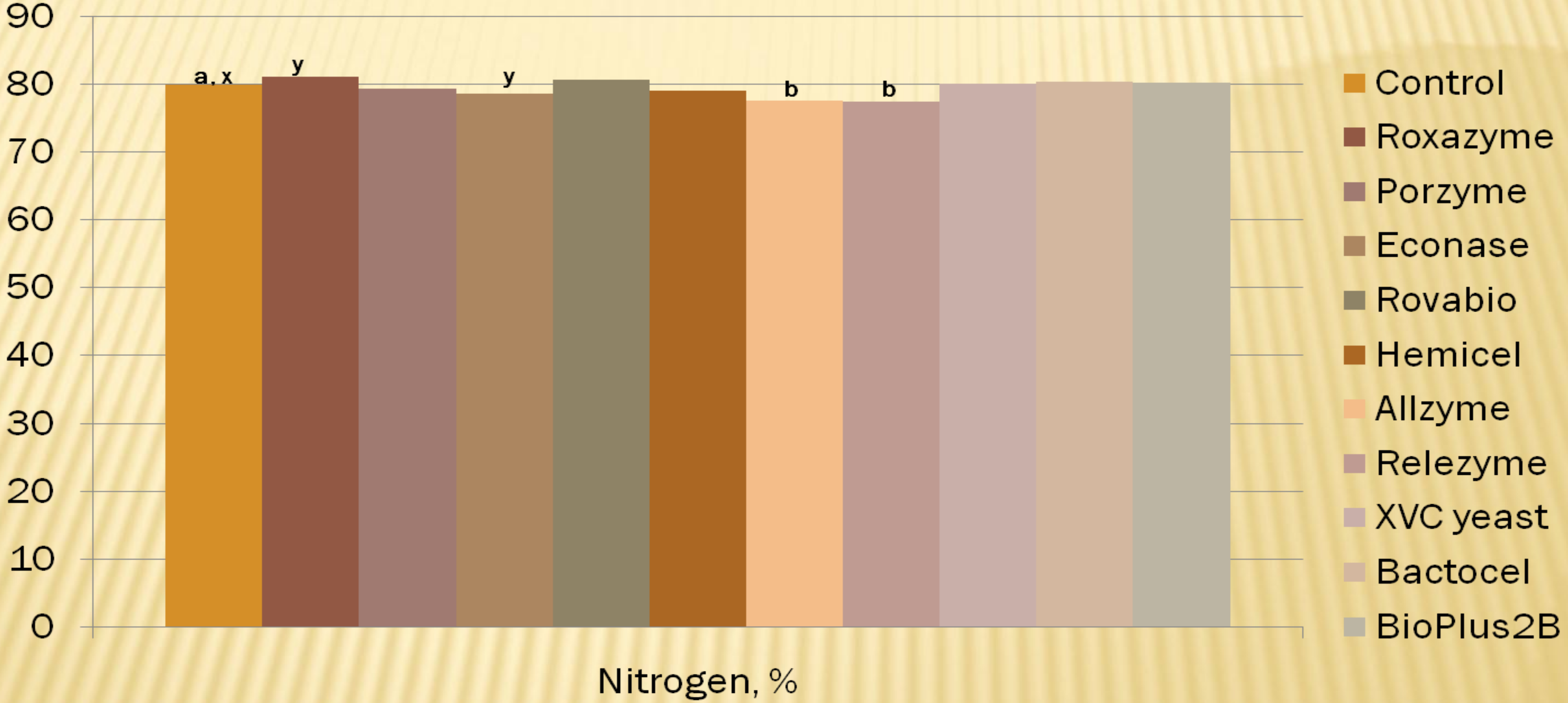
[a, b] Control > Econase, Allzyme, and Releez-a-zyme ($P < 0.01$).

[x, y] Control > Porzyme and Hemicel ($P < 0.10$).

Apparent Ether Extract Digestibility (%)

[x, y] Control > Releez-a-zyme ($P < 0.10$).

Apparent Nitrogen Digestibility (%)

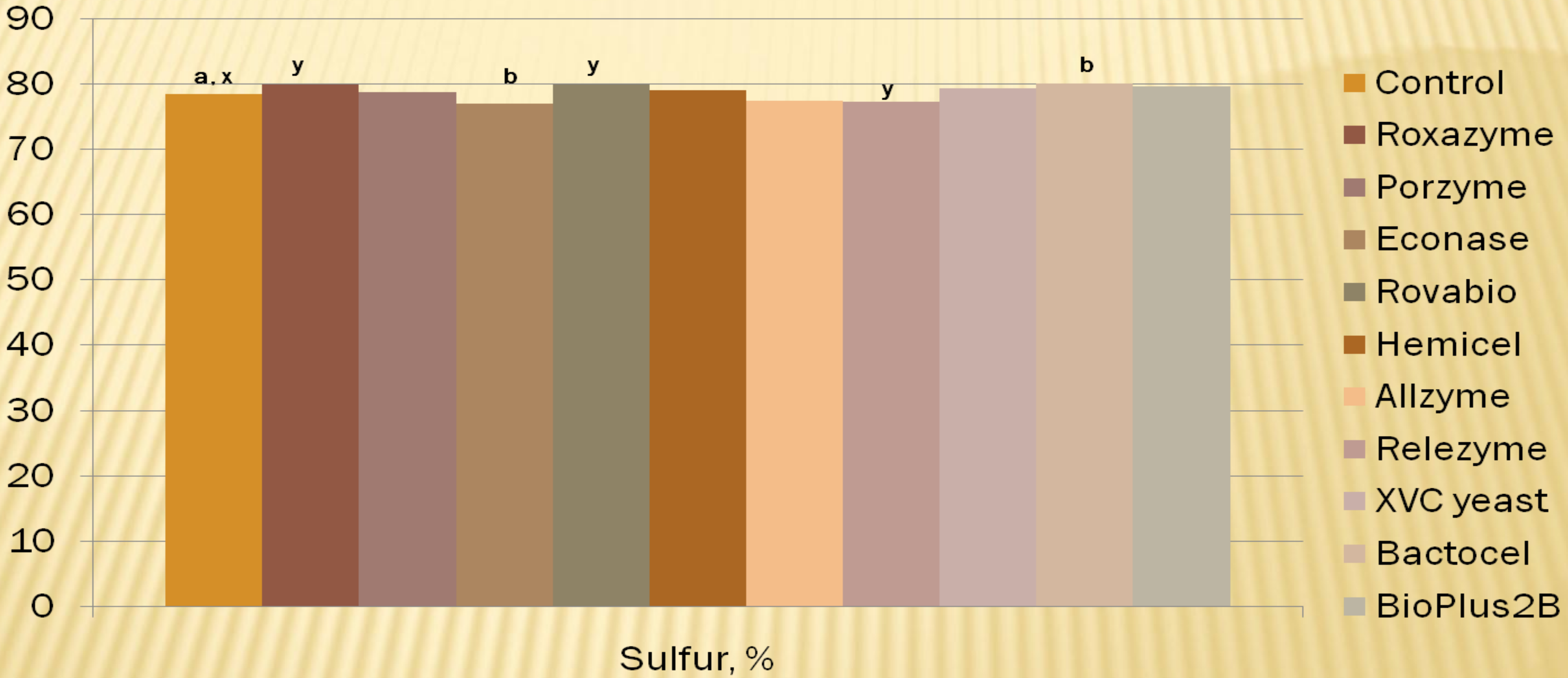


[a, b] Control > Allzyme and Releez-a-zyme ($P < 0.01$).

[x, y] Control > Econase ($P < 0.10$).

[x, y] Roxazyme > Control ($P < 0.10$).

Apparent Sulfur Digestibility (%)



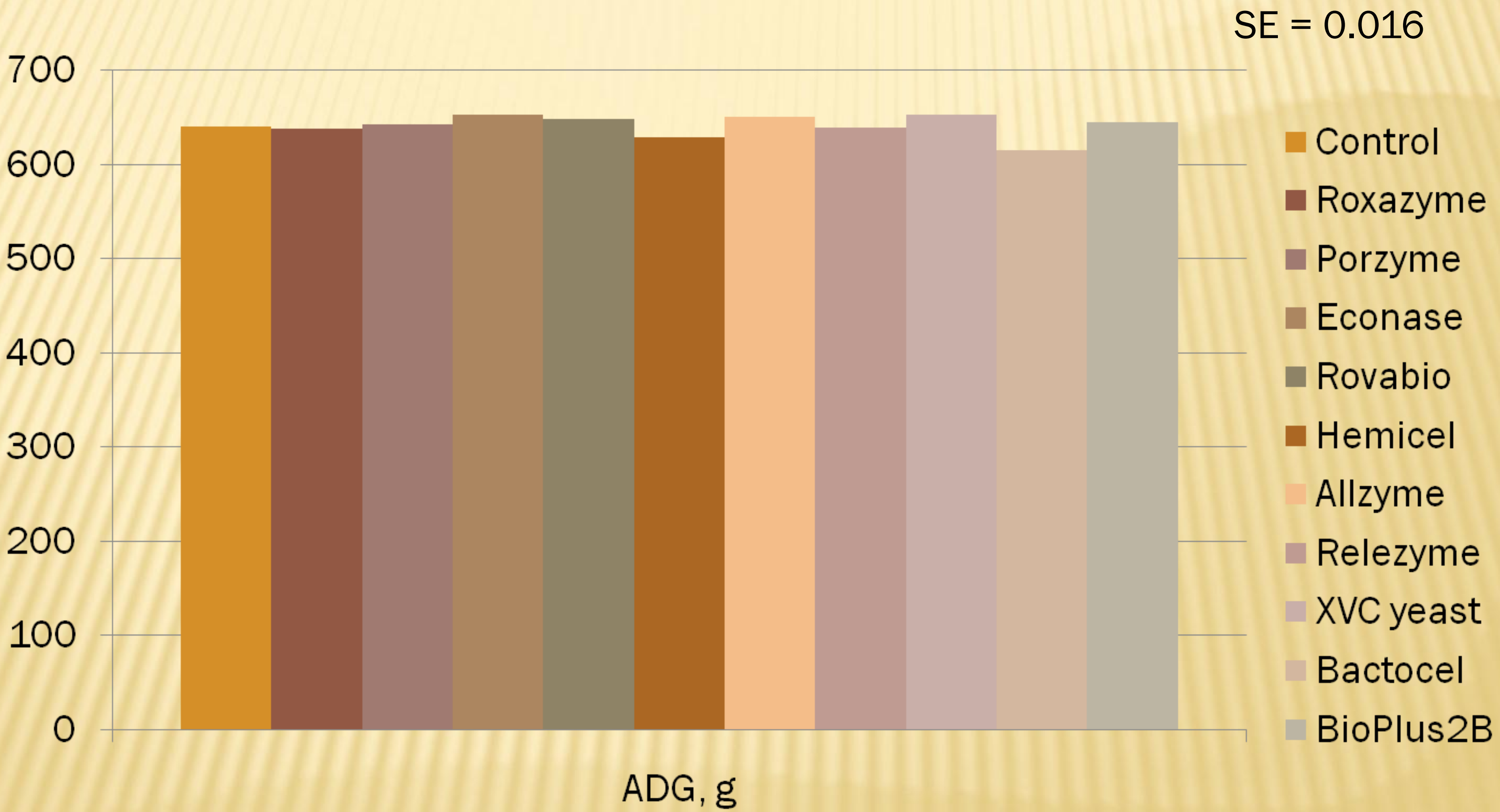
[a, b] Control > Econase ($P < 0.01$).

[a, b] Bactocel > Control ($P < 0.01$).

[x, y] Control > Releez-a-zyme ($P < 0.10$).

[x, y] Roxazyme and Rovabio > Control ($P < 0.10$).

Average Daily Gain



No significant treatment differences vs. control (P > 0.10).

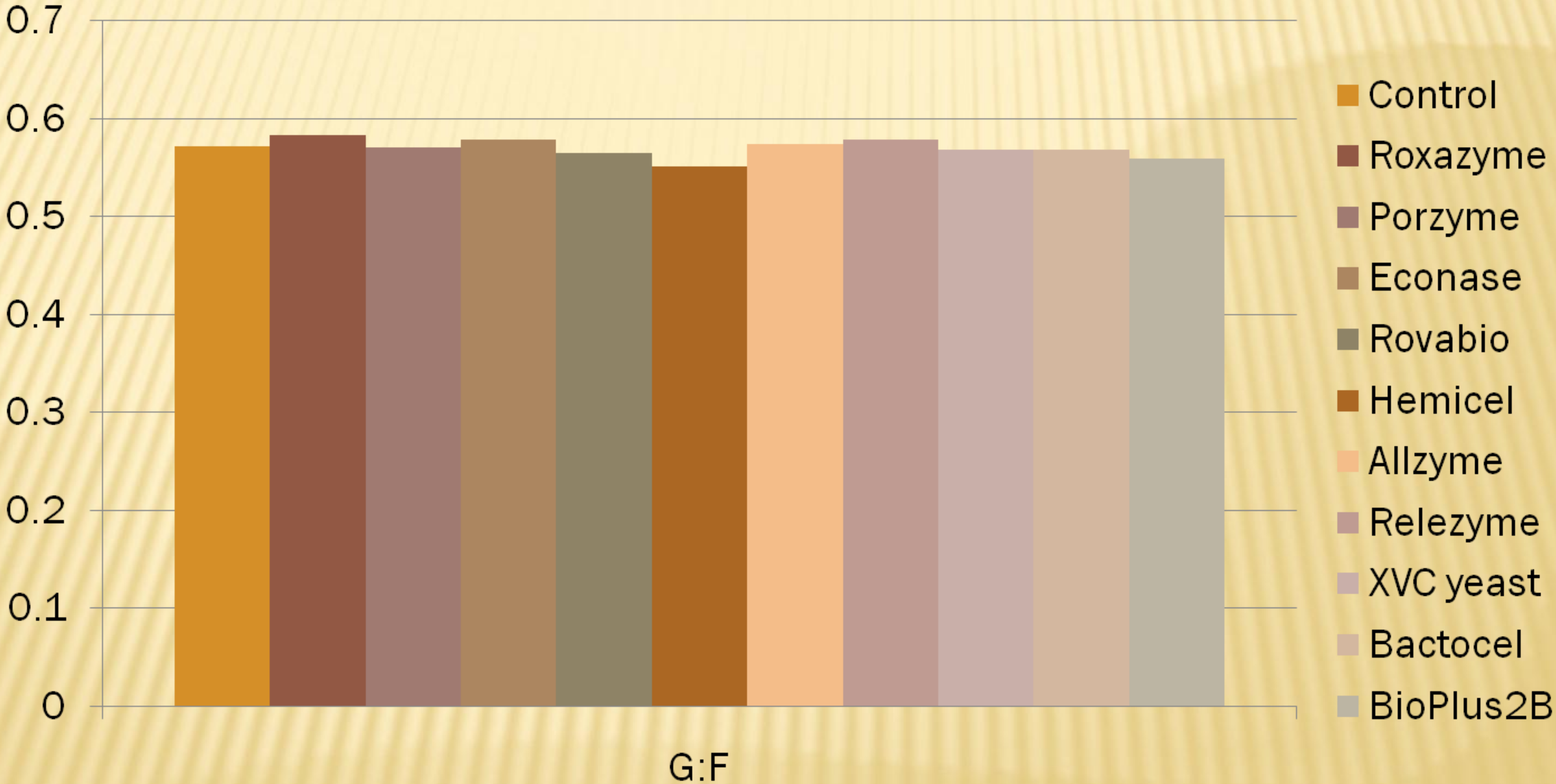
Average Daily Feed Intake

SE = 0.030

No significant treatment differences vs. control (P > 0.10).

Gain:Feed

SE = 0.011

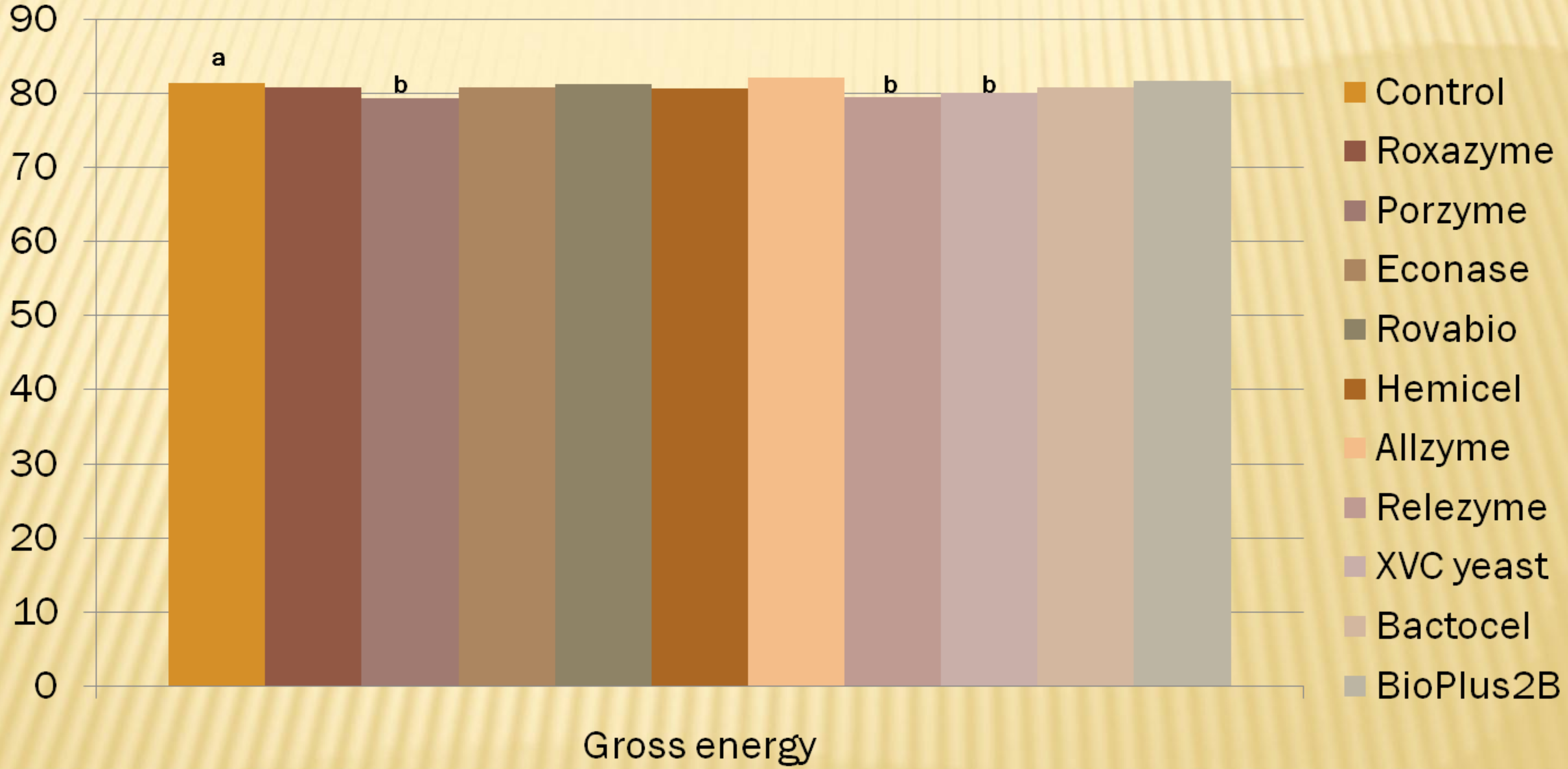


No significant treatment differences vs. control (P > 0.10).

Results

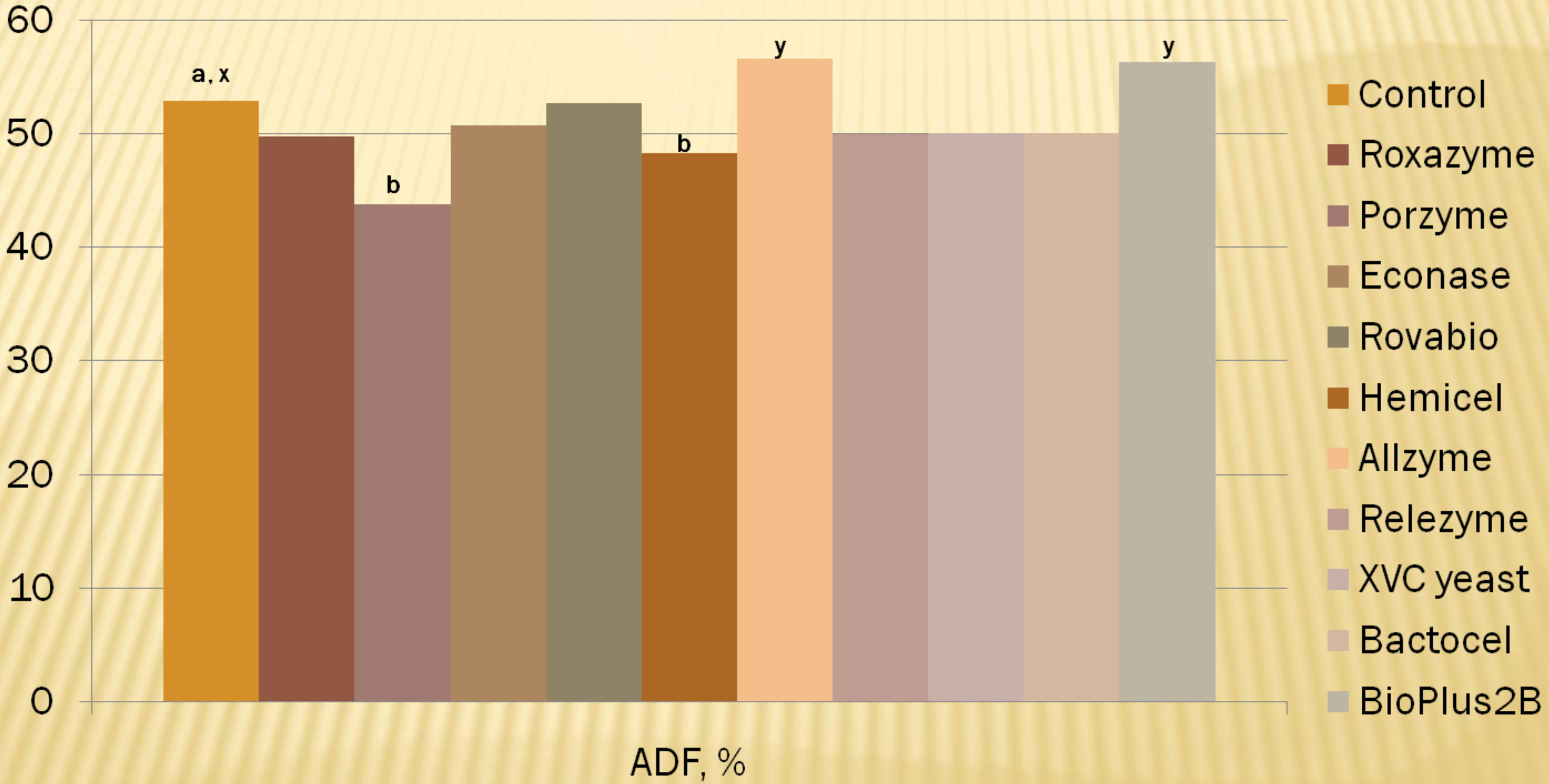
- Finisher Pigs (98 – 132 kg BW)
- 30% DDGS Diets with Feed Additives

Apparent GE Digestibility (%)



[a, b] Control > Porzyme, Releez-a-zyme, and XVC Yeast ($P < 0.05$).

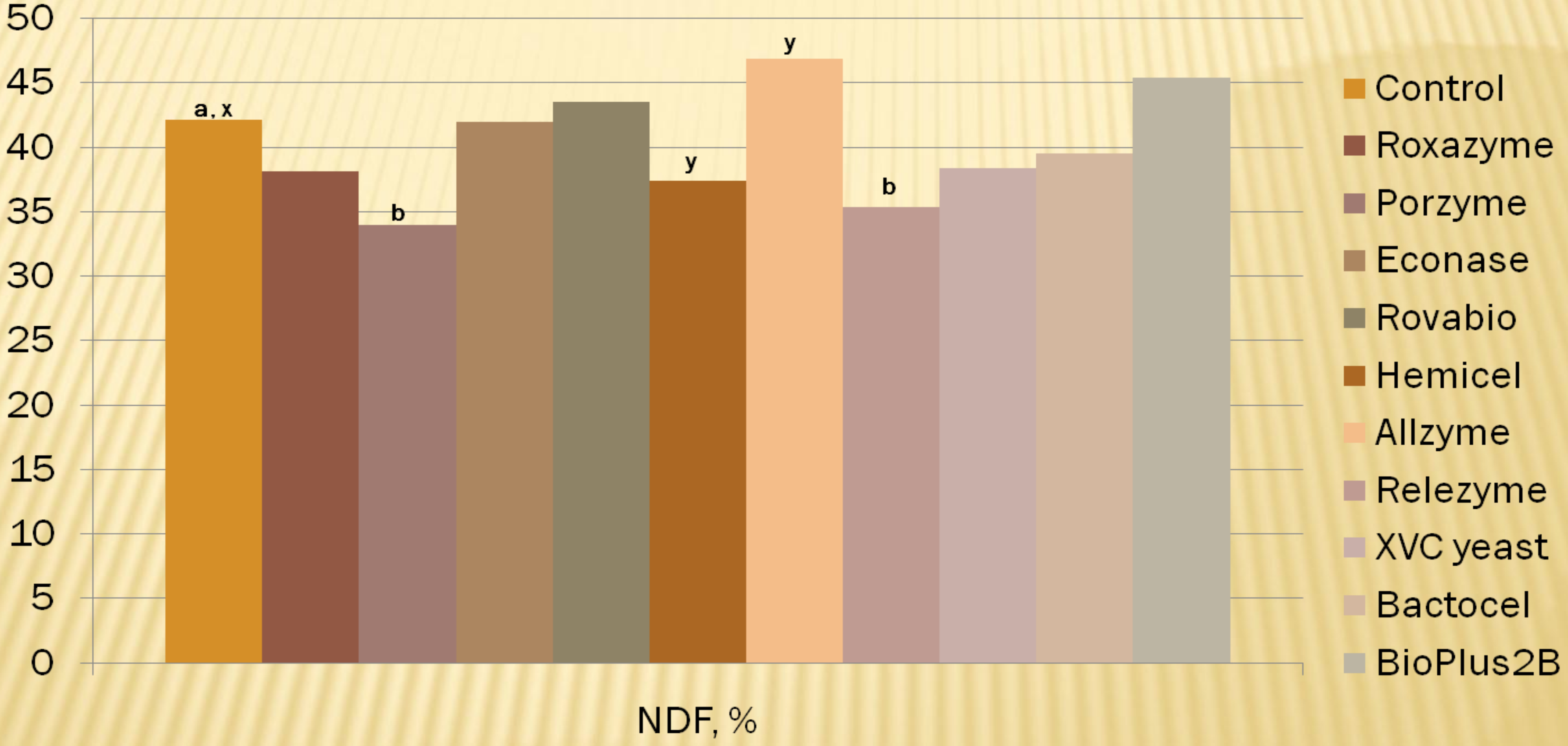
Apparent ADF Digestibility (%)



[a, b] Control > Porzyme and Hemicel ($P < 0.01$).

[x, y] Allzyme and BioPlus 2B > Control ($P < 0.10$).

Apparent NDF Digestibility (%)

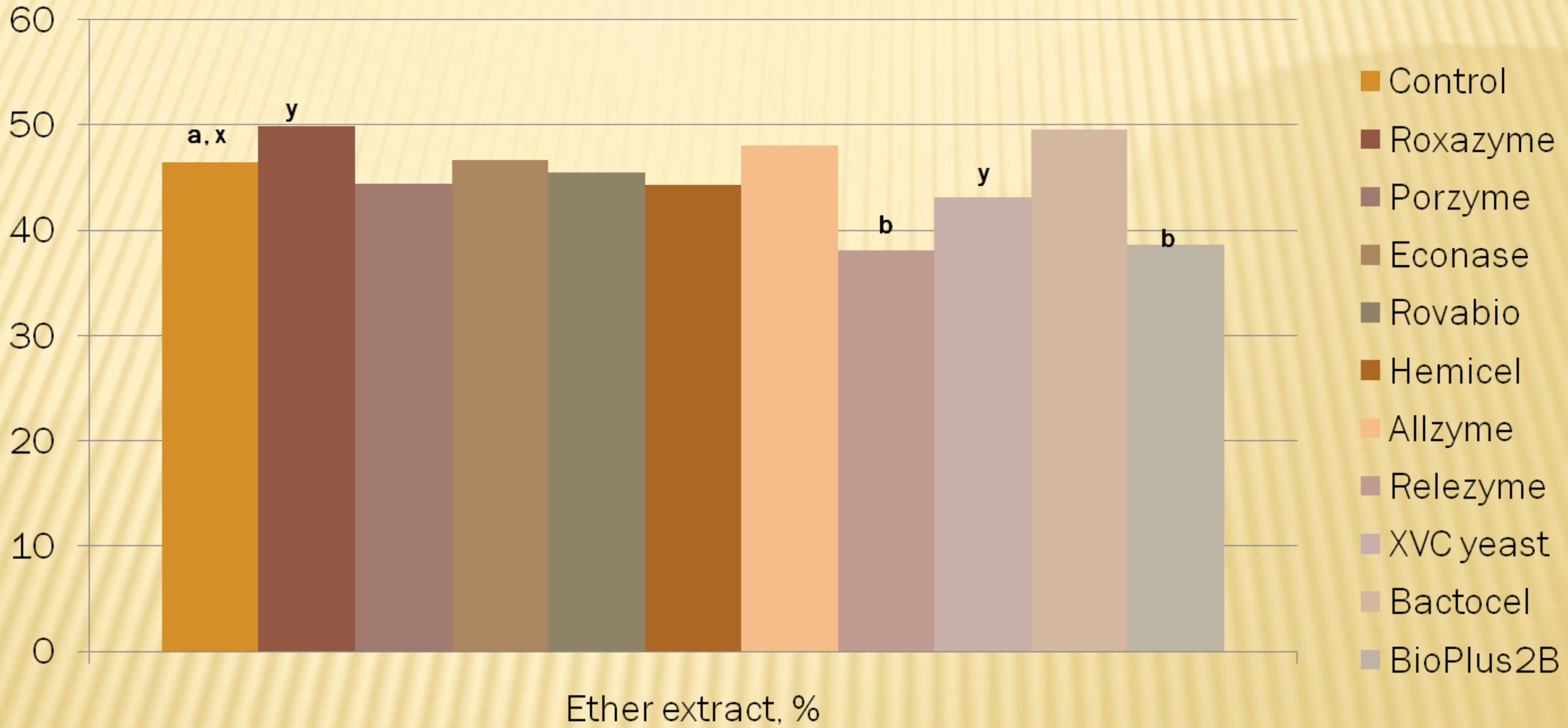


[a, b] Control > Porzyme and Releez-a-zyme ($P < 0.02$).

[x, y] Control > Hemicel ($P < 0.10$).

[x, y] Allzyme > Control ($P < 0.10$).

Apparent Ether Extract Digestibility (%)

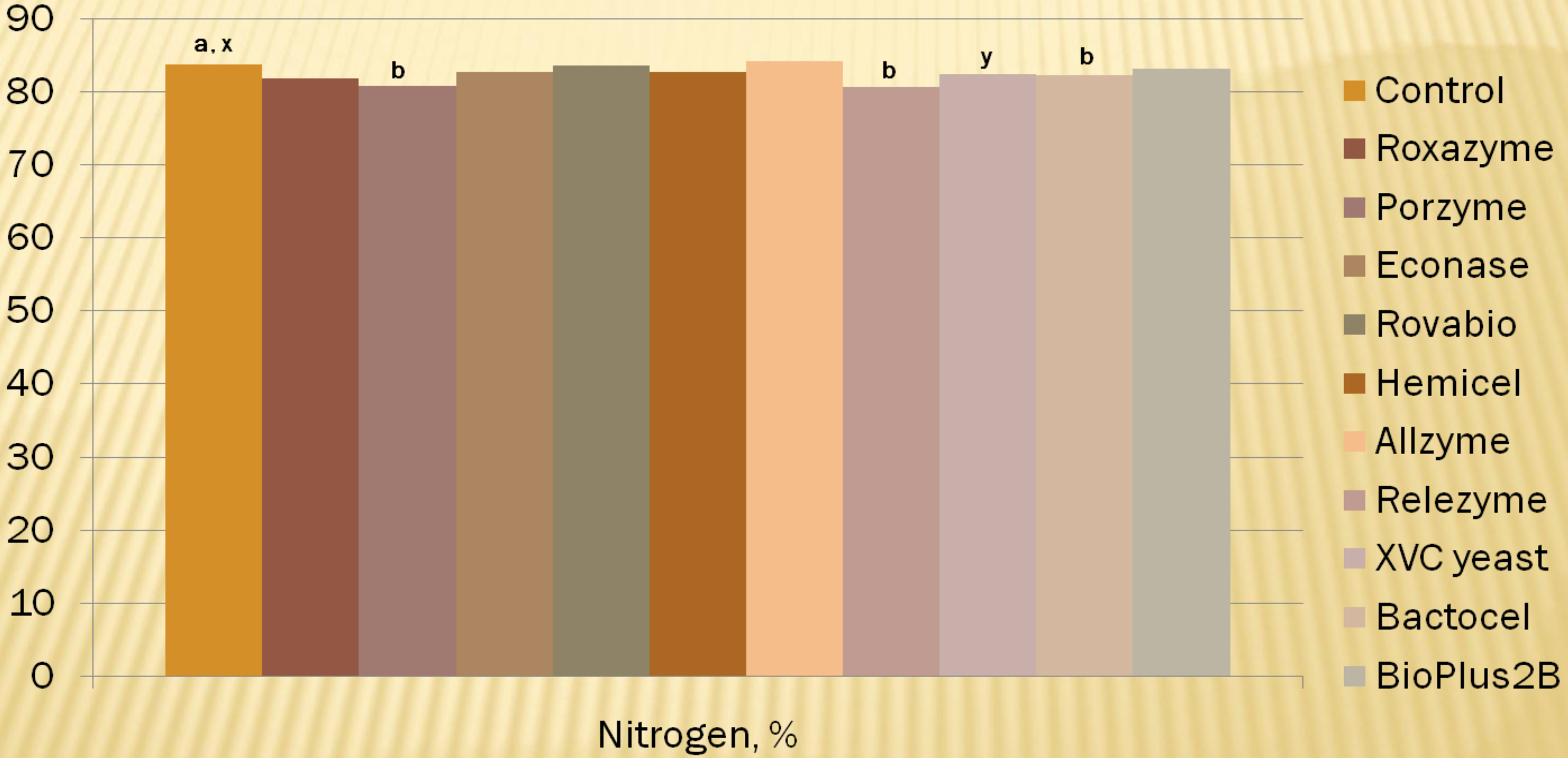


[a, b] Control > Releez-a-zyme and BioPlus 2B ($P < 0.01$).

[x, y] Control > XVC Yeast ($P < 0.10$).

[x, y] Roxazyme > Control ($P < 0.10$).

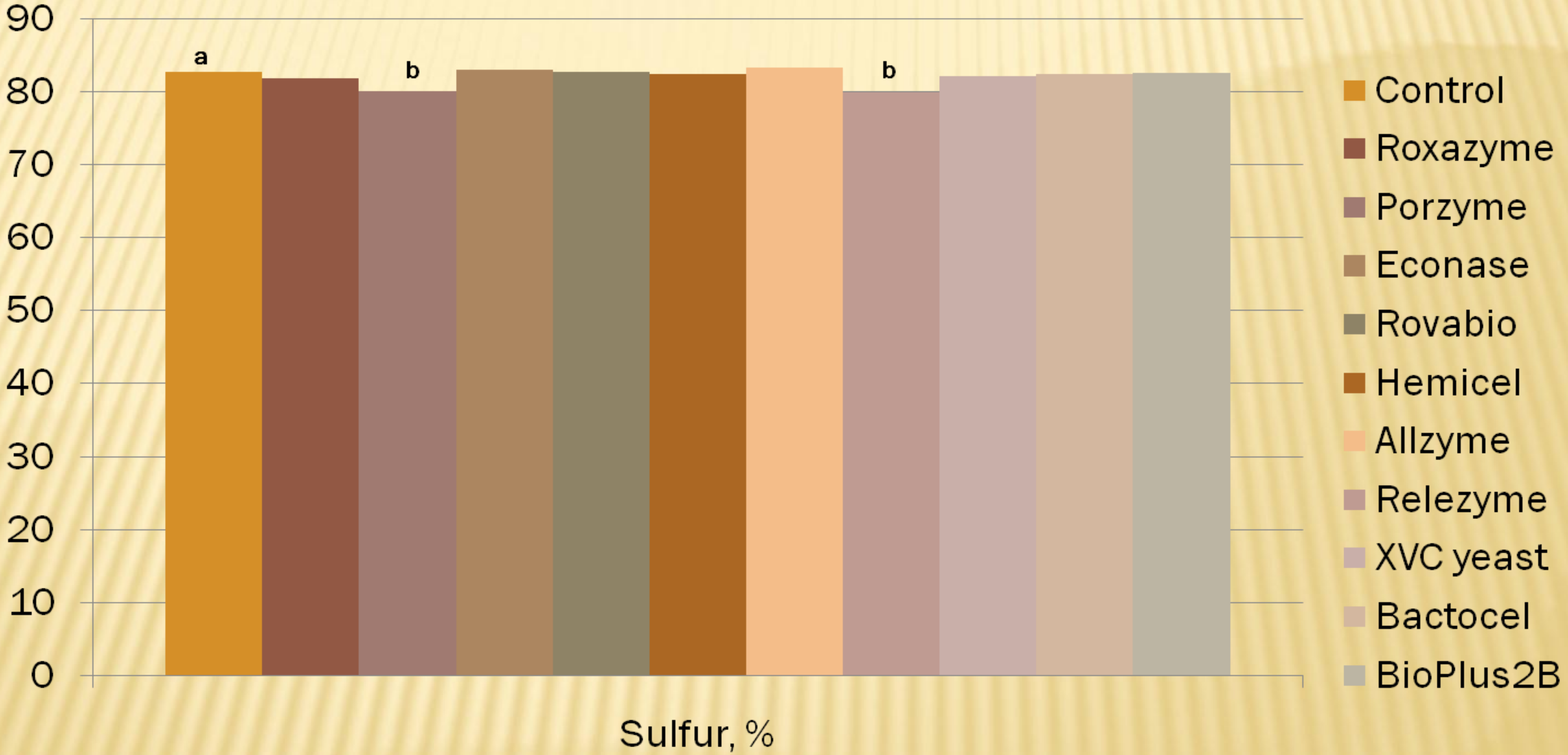
Apparent Nitrogen Digestibility (%)



[a, b] Control > Porzyme, Releez-a-zyme, and Bactocel ($P < 0.05$).

[x, y] Control > XVC Yeast ($P < 0.10$).

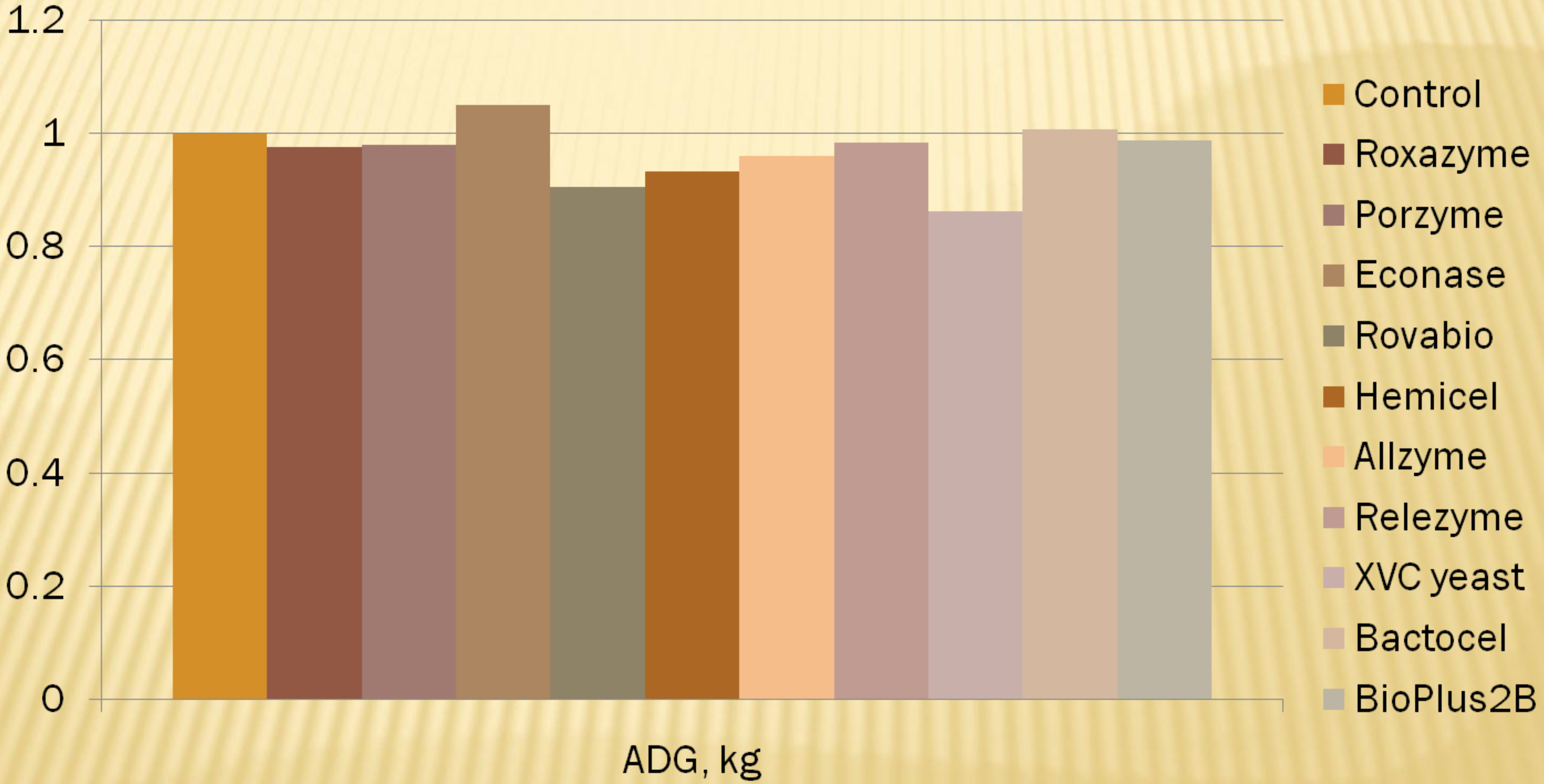
Apparent Sulfur Digestibility (%)



[a, b] Control > Porzyme and Releez-a-zyme ($P < 0.01$).

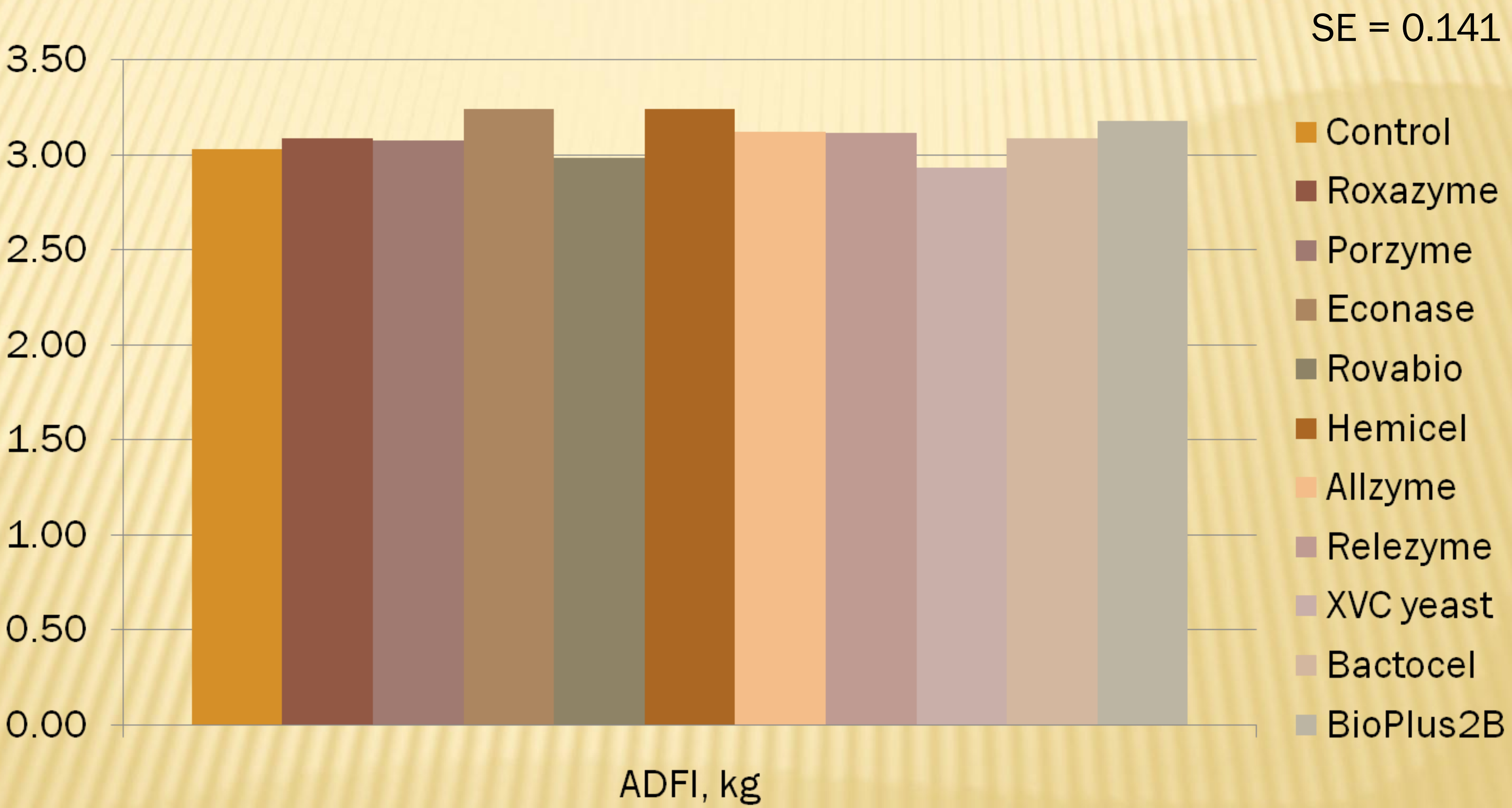
Average Daily Gain

SE = 0.057



No significant treatment differences vs. control ($P > 0.10$).

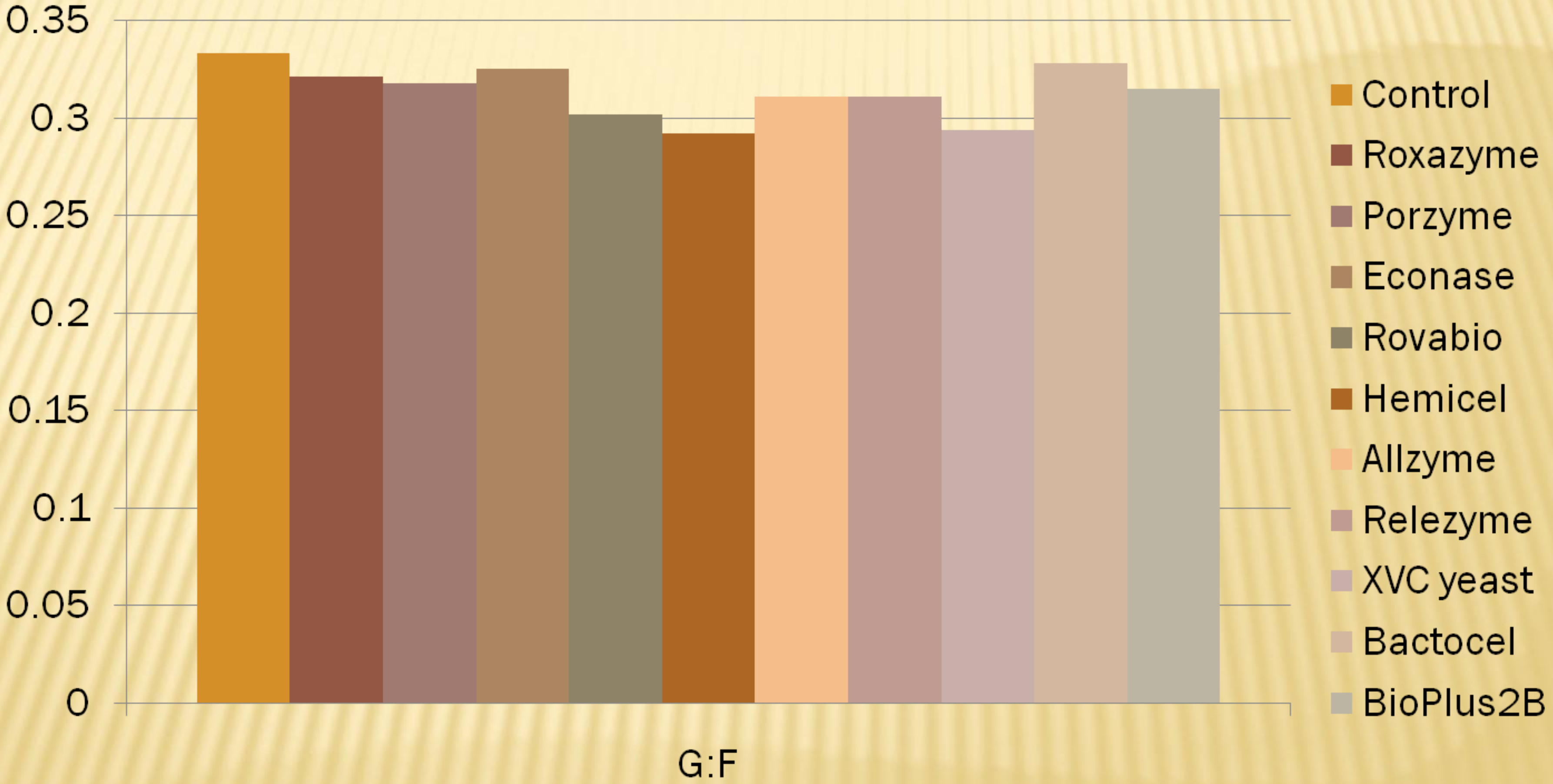
Average Daily Feed Intake



No significant treatment differences vs. control ($P > 0.10$).

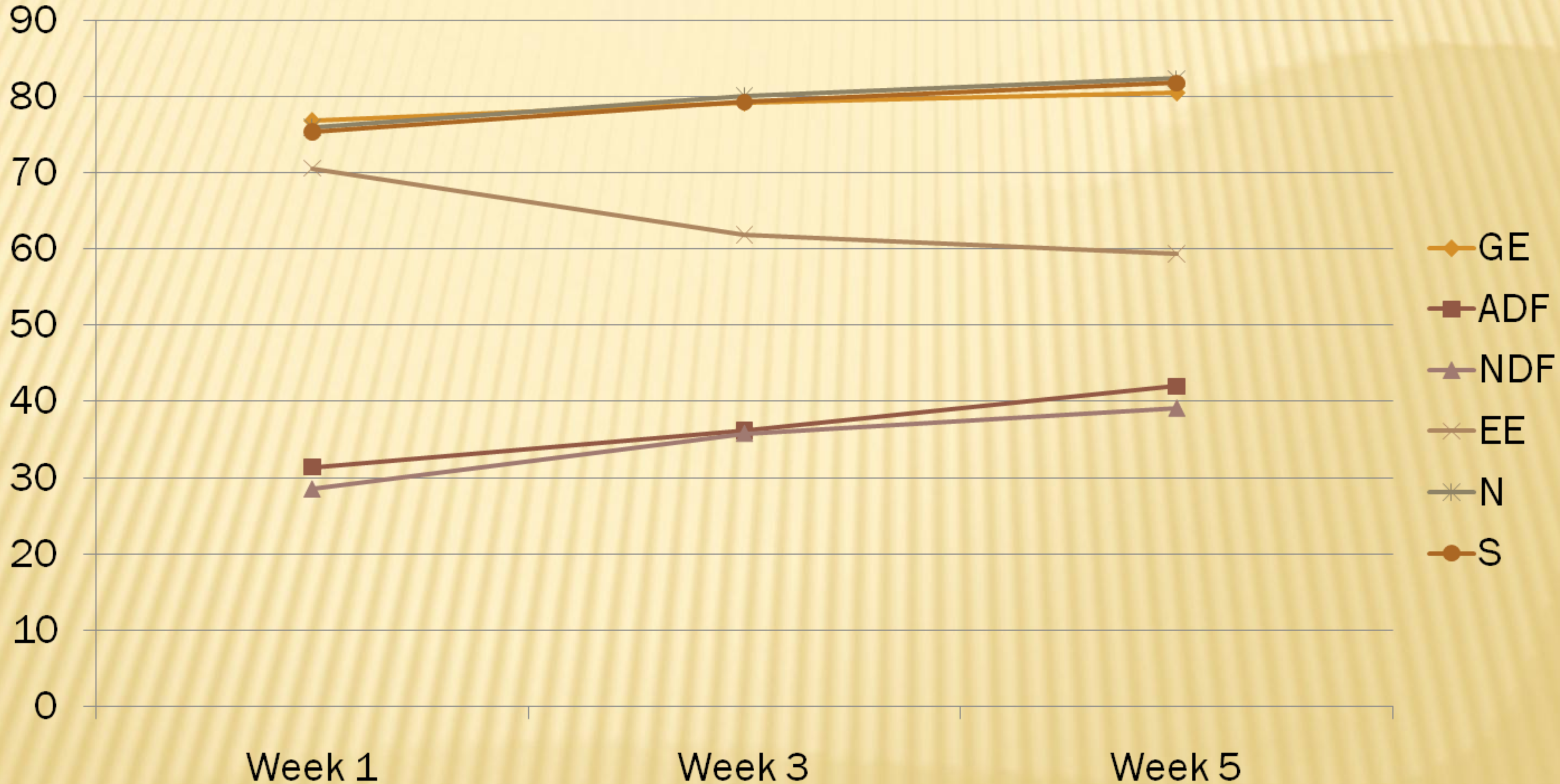
Gain:Feed

SE = 0.014



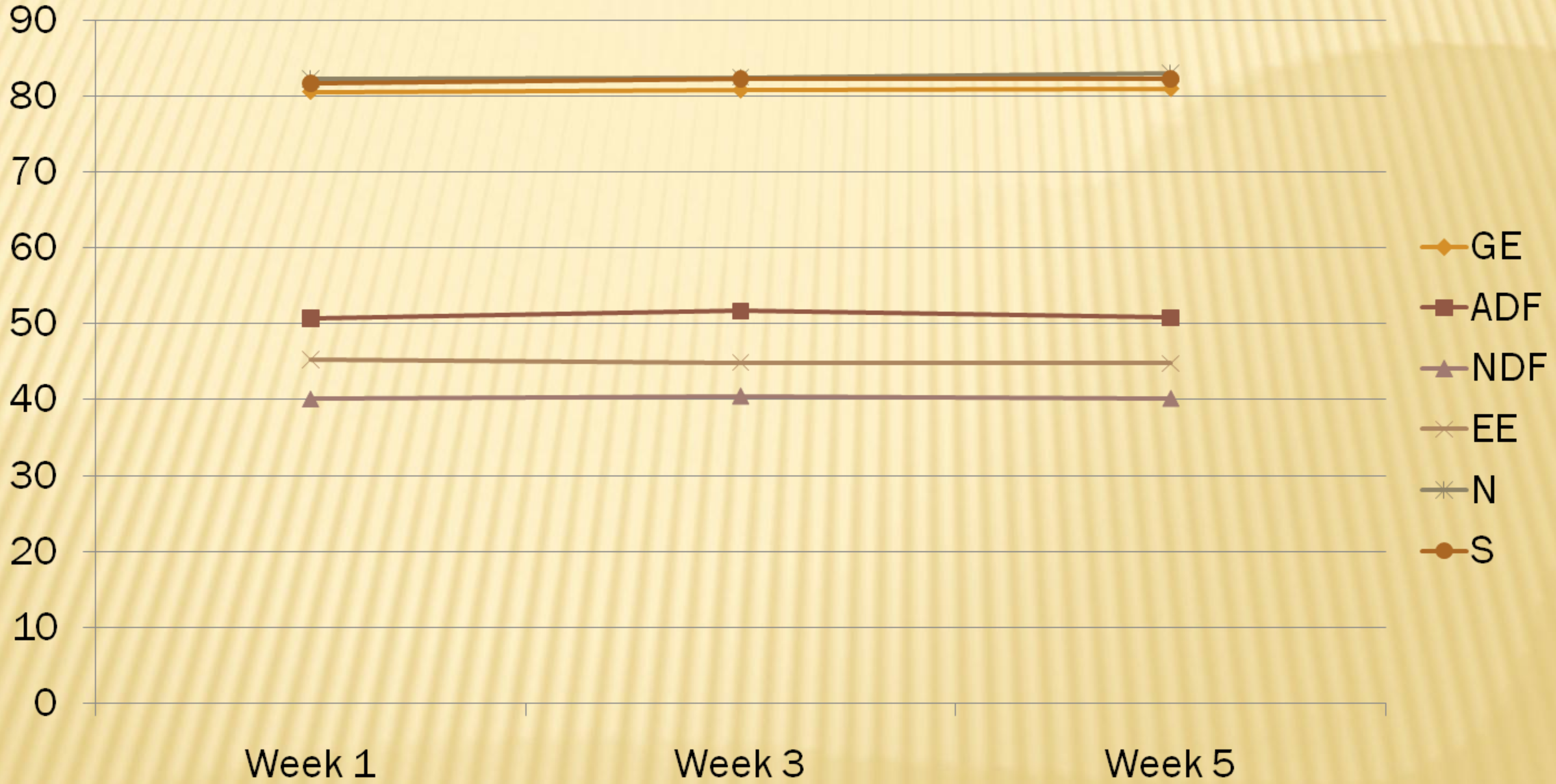
No significant treatment differences vs. control (P > 0.10).

Apparent GE and Nutrient Digestibility (%) Changes During a 5-week Starter Feeding Period



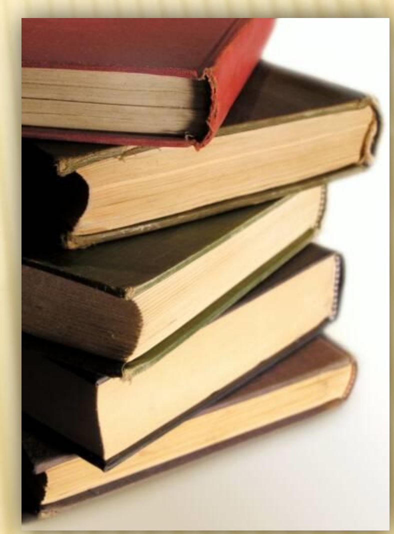
Significant effect ($P < 0.01$) of week for all measurements.

Apparent GE and Nutrient Digestibility (%) Changes During a 5-week Finisher Feeding Period



No significant difference by week for any measurement.

Use of Carbohydrases in Pig Diets Have Yielded Mixed Responses



- Improved nutrient digestibility
  - Li et al. (1996)
  - Barrera et al. (2004)
  - Nortey et al. (2007)
  - Sterk et al. (2007)
- No improvement in nutrient digestibility
  - Zijlstra et al. (2004)
  - Diebold et al. (2005)
- Improved nutrient digestibility does not always lead to improved growth performance
  - Inborr et al. (1993)
  - Officer (1995)
  - Olukosi et al. (2007)

How Do Our Results Compare to Others Studies?

- Adding enzymes to DDGS diets resulted in:
  - No improvement in growth performance
    - Nursery pigs
      - Jones et al. (2010) - Easyzyme Mixer 1, Hemicell-W, Porzyme
      - Benz et al. (2010) - Livestock Answer (amylases, proteases, cellulases, lipases, phytases)
    - Finishing pigs
      - Jacela et al. (2010) - Hemicell, REAP, Allzyme, Nutrase
      - Benz et al. (2010) - Livestock Answer

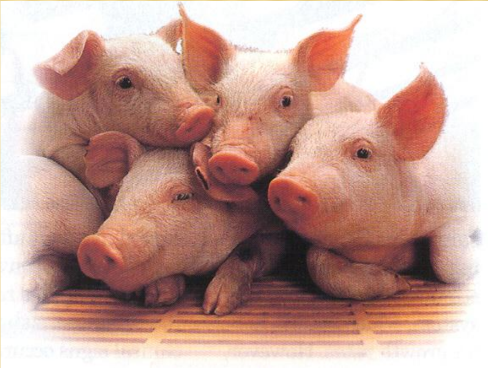
How Do Our Results Compare to Others Studies?

- Adding enzymes to DDGS diets resulted in:
  - Improvement in growth performance
    - Nursery pigs
      - Spencer et al. (2007) - α-galactosidase, galactomannanase, xylanase, and β-glucanase
    - Grower-finisher pigs
      - Yoon et al. (2010) - β-mannase
  - Improvement in energy and nutrient digestibility
    - Nursery pigs
      - Jendza et al. (2009) - Porzyme (xylanase)
    - Finishing pigs
      - Yoon et al. (2010) - β- mannase
      - Feoli et al. (2008) – β- glucanase, protease, α amylase, xylanase

Why Are Enzyme Responses Generally Better in Poultry Diets Compared to Swine Diets?

- Beneficial effects of enzyme supplementation in poultry diets have been associated with reduced digesta viscosity in poultry (Choct and Annison, 1992)
  - Improved nutrient digestion
  - Improved growth performance

- NSP increase digesta viscosity in pigs
  - Physical barrier that traps nutrients in feedstuffs, protecting them from enzyme activity (Grieshop et al., 2001)



Why Don't Enzymes Give Consistent Positive Responses?

- Diets are not deficient in nutrients
- Incorrect enzymes are used for diet substrates
- Enzyme activity of the product may be low
- Antinutritional factors interfere with enzyme activity
- Low levels of NSP (inadequate substrate) in diets
- Age of pig (young > older)
- Diet particle size
- Improvement in hindgut digestibility does not lead to improved nutrient absorption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