2023

THE ALMOND CONFERENCE

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Feed More Hulls to Cattle and Poultry

Moderator: Guangwei Huang (ABC)

Speakers: Pratima Acharya Adhikari (MSU), Katie Swanson (UC Davis), Hamed El Mashad (UC Davis), Keith Schneller (ABC)

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Inclusion Of Almond Hulls On Performance Parameters And Egg Quality In Laying Hens

Dr. Pratima Adhikari

Associate Professor / MS State University

Outline

- Introduction
- Research Methods
- Results
- Summary and Conclusion

Introduction: Almond hulls

- Almond nuts have three parts: the inner kernel, the middle shell portion, and an outer hull [1].
- Almond hulls (AH) generated in California are solely used as a supplement feed for dairy cows at present[1].
- AH are rich in carbohydrates, mainly non-starch polysaccharides (NSP); these include: cellulose, hemicellulose, and pectin, in addition to soluble sugars [1].

1.Huang & Lapsley, 2019.

Proximate analysis* of almond hulls

Almond hulls Sample	Moisture	Protein	Fiber	Starch	NDF	ADF	Sugar	Ash	Fat
	%				%, as is				
Sample 1	9.94	5.00	16.45	0.38	48.25	29.11	14.95	8.92	3.28
Sample 2	9.02	5.00	15.71	0.01	47.79	25.82	17.28	8.17	2.6
Average	9.48	5.00	16.08	0.20	48.02	27.47	16.12	8.55	2.94

Sugar profile almond hulls

Product Name	Fraction	Constituent sugars (g/100 g)									Total		Lignin	
		rha	fuc	ara	xyl	man	gal	glu	GlcA	GalA	g/100 g	SD	g/100 g	SD
Almond Hulls	Soluble NSP	0.2	0.0	2.5	0.3	0.5	1.3	0.7	0.0	3.1	8.6	0.0		
	Insoluble NSP	0.2	0.1	1.5	2.7	0.7	1.3	8.1	0.0	0.5	15.1	0.0		
	Total NSP	0.4	0.2	4.0	3.0	1.3	2.6	8.7	0.0	3.6	23.7	0.2	5.3	0.5
	Direct	0.4	0.2	4.1	3.6	1.4	2.7	22.5	0.0	6.0	40.9	0.1		
	*Direct - Total	0.0	0.1	0.1	0.6	0.1	0.1	13.8	0.0	2.4	17.2			

NSP, non-starch polysaccharides; rha, rhamnose; fuc, fucose; ara, arabinose; xyl, xylose; man, mannose; gal, galactose, glu, glucose; GlcA, glucuronic acid; GalA, galacturonic acid

*AOAC procedure.

NSP: Non-starch polysaccharides

Laying hen study- MS State University

LAYER 1 - 22-70 WEEKS OF AGE
LAYER 2 - 44–70 WEEKS (POST-PEAKING PHASE):

Treatment	Description
T1	Standard corn-SBM
T2	5% AH
T3	5% AH+Enzyme
T4	10% AH
T5	10% AH+Enzyme
T6	15% AH
T7	15% AH+Enzyme

- Design- 2 x 3 factorial + 1 control
- Hens received 100 g of feed daily
- 504 hens were placed in 126 cages,
  - 4 hens/cage
  - 18 replicates/treatment
- Enzyme inclusion: 136 g/ton

Feed Composition (22-41 weeks) – energy balance with animal fat

Ingredient	T 1	T 2 5% AH	T 3 5% AH + E	T 4 10% AH	T 5 10% AH + E	T 6 15% AH	T 7 15% AH + E
Corn	67.19	61.98	61.98	54.36	54.36	46.75	46.75
Soybean meal	19.99	18.45	18.45	19.12	19.12	19.78	19.78
Calcium carbonate	9.53	9.52	9.52	9.51	9.51	9.49	9.49
Poultry fat	1.51	2.98	2.98	4.87	4.87	6.77	6.77
Dicalcium phosphate.	0.86	0.91	0.91	0.93	0.93	0.95	0.95
Vitamin and trace mineral premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sodium bicarbonate	0.21	0.24	0.24	0.29	0.29	0.35	0.35
L-methionine	0.20	0.23	0.23	0.25	0.25	0.26	0.26
Salt	0.19	0.17	0.17	0.13	0.13	0.09	0.09
L-lysine 78.8% (HCl)	0.012	0.077	0.077	0.075	0.075	0.073	0.073
Phytase	0.008	0.008	0.008	0.008	0.008	0.008	0.008
L-isoleucine	0.007	0.055	0.055	0.061	0.061	0.067	0.067
L-threonine 98.5%	0.003	0.047	0.047	0.053	0.053	0.059	0.059
L-valine	0.000	0.047	0.047	0.059	0.059	0.071	0.071
Enzyme	0.000	0.000	0.015	0.000	0.015	0.000	0.015
Almond hulls	0.000	5.000	5.000	10.000	10.000	15.000	15.000
Calculated composition (%)							
Dry matter	88.89	89.21	89.21	89.58	89.58	89.96	89.96
Crude protein	14.37	13.65	13.65	13.61	13.61	13.56	13.56
Crude fat	4.67	6.03	6.03	7.74	7.74	9.45	9.45
Crude fiber	2.35	2.99	2.99	3.69	3.69	4.39	4.39
Calcium	4.10	4.10	4.10	4.10	4.10	4.10	4.10
Available phos.	0.44	0.44	0.44	0.44	0.44	0.44	0.44
M.E. (kcal/lb)	1,270.00	1,270.00	1,270.00	1,270.00	1,270.00	1,270.00	1,270.00
Digestible lysine	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Digestible methionine	0.415	0.430	0.430	0.437	0.437	0.445	0.445
Digestible threonine	0.476	0.482	0.482	0.482	0.482	0.482	0.482
Digestible tryptophan	0.147	0.136	0.136	0.136	0.136	0.136	0.136
Digestible valine	0.591	0.591	0.591	0.591	0.591	0.591	0.591
Digestible isoleucine	0.530	0.537	0.537	0.537	0.5372	0.5372	0.537

Feed Composition (44-62 weeks) – all energy coming from hulls

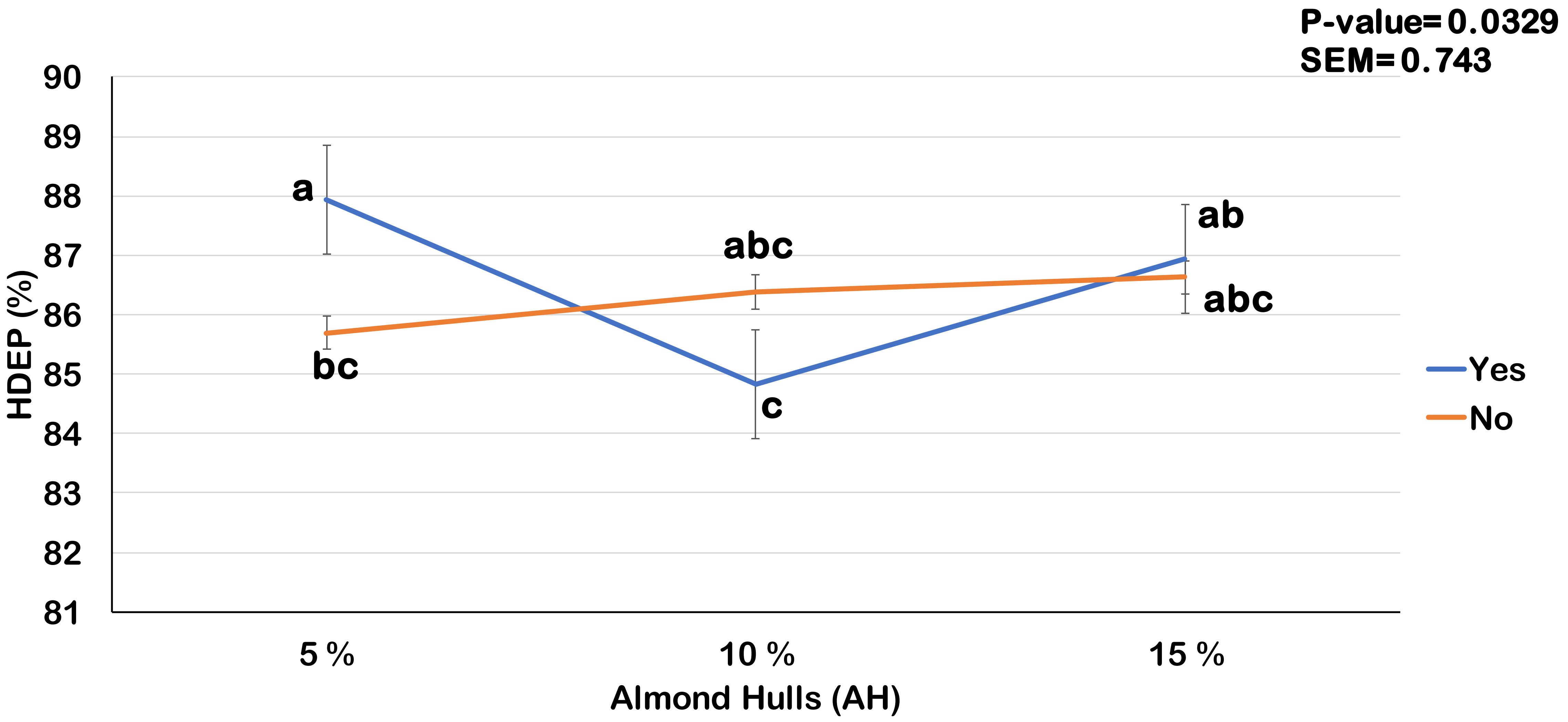
Ingredient	T 1	T 2 5% AH	T 3 5% AH + E	T 4 10% AH	T 5 10% AH + E	T 6 15% AH	T 7 15% AH + E
Corn	64.50	58.83	58.83	53.77	53.77	50.71	50.71
Soybean meal	21.39	22.02	22.02	22.24	22.24	20.60	20.60
Calcium carbonate	9.74	9.71	9.71	9.69	9.69	9.67	9.67
Poultry fat	2.61	2.57	2.57	2.39	2.39	1.89	1.89
Dicalcium phosphate	0.92	0.92	0.92	0.91	0.91	0.92	0.92
Vitamin and trace mineral premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-methionine 98.5%	0.231	0.240	0.240	0.251	0.251	0.278	0.278
Salt, plain (NaCl)	0.303	0.063	0.063	0.025	0.025	0.000	0.000
Sodium bicarbonate	0.000	0.347	0.347	0.400	0.400	0.433	0.433
Phytase	0.008	0.008	0.008	0.008	0.008	0.008	0.008
L-lysine 78.8% (HCl)	0.011	0.005	0.005	0.010	0.010	0.071	0.071
L-isoleucine	0.000	0.000	0.000	0.007	0.007	0.044	0.044
L-valine	0.001	0.006	0.006	0.017	0.017	0.058	0.058
L-threonine 98.5%	0.009	0.012	0.012	0.020	0.020	0.053	0.053
Almond hulls	0.000	5.000	5.000	10.000	10.000	15.000	15.000
Enzyme	0.000	0.000	0.015	0.000	0.015	0.000	0.015
Calculated composition (%)							
Dry matter	88.79	88.95	88.95	89.10	89.10	89.19	89.19
Crude protein	14.95	15.04	15.04	15.00	15.00	14.35	14.35
Crude fat	4.95	4.91	4.91	4.76	4.76	4.30	4.30
Crude fiber	2.99	3.66	3.66	4.34	4.34	4.99	4.99
Calcium	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Available phos.	0.43	0.43	0.43	0.43	0.43	0.43	0.43
M.E. (kcal/lb)	1,270.00	1,230.00	1,230.00	1,190.00	1,190.00	1,150.00	1,150.00
Digestible lysine	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Digestible methionine	0.4399	0.4438	0.4438	0.4491	0.4491	0.4615	0.4615
Digestible threonine	0.4964	0.4964	0.4964	0.4964	0.4964	0.4964	0.4964
Digestible tryptophan	0.1637	0.1641	0.1641	0.1625	0.1625	0.151	0.151
Digestible valine	0.5916	0.5916	0.5916	0.5916	0.5916	0.5916	0.5916
Digestible isoleucine	0.5372	0.5372	0.5372	0.5372	0.5372	0.5372	0.5372

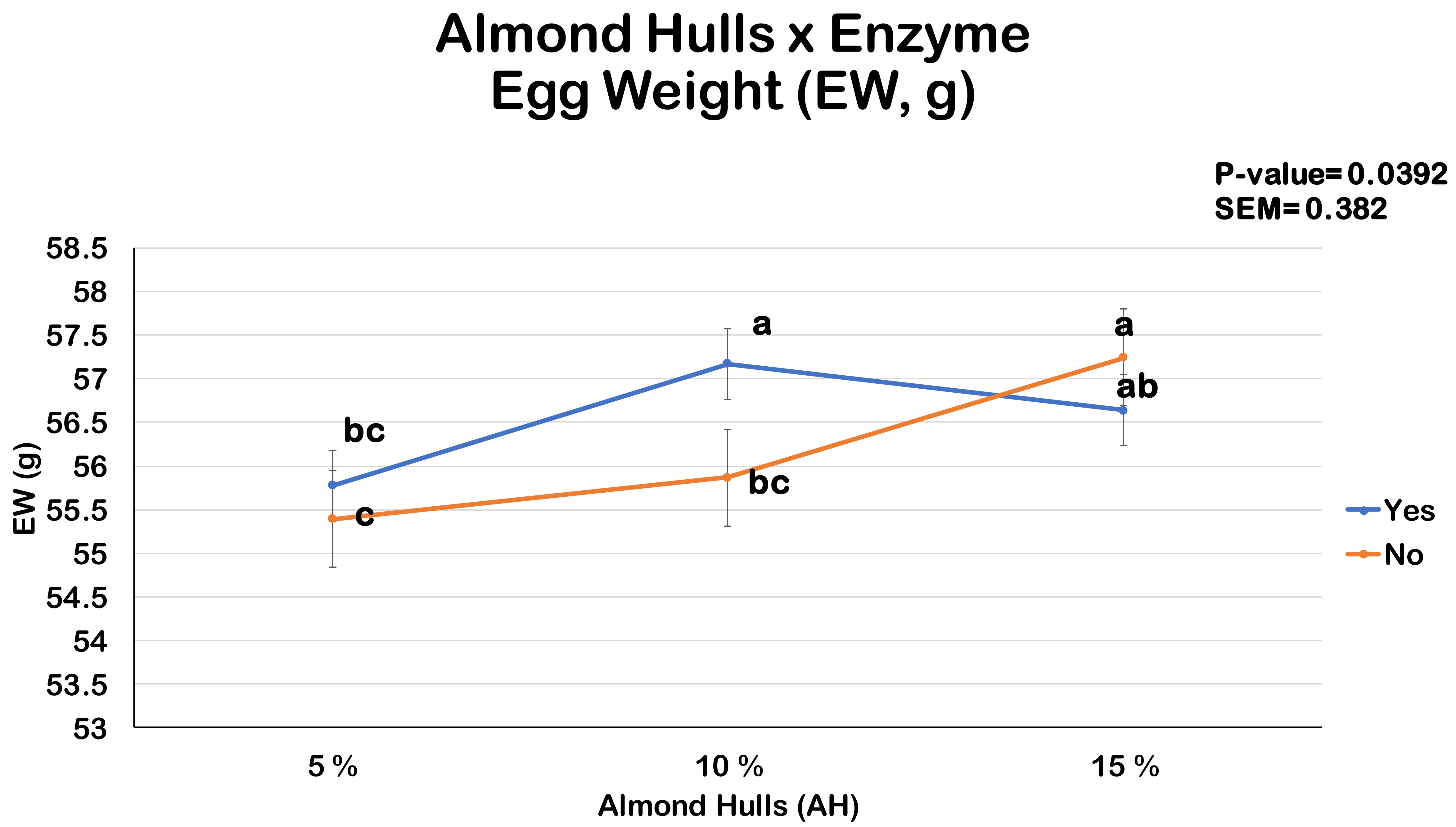
Feed Composition (63 – 70 weeks) – energy balance with fat

Ingredient	T 1	T 2 5% AH	T 3 5% AH + E	T 4 10% AH	T 5 10% AH + E	T 6 15% AH	T 7 15% AH + E
Corn	65.148	60.167	60.167	52.785	52.785	45.403	45.403
Soybean meal	20.783	19.130	19.130	19.684	19.684	20.238	20.238
Calcium carbonate	9.750	9.749	9.749	9.736	9.736	9.724	9.724
Poultry fat	2.564	3.947	3.947	5.716	5.716	7.485	7.485
Dicalcium phosphate	0.935	0.971	0.971	0.989	0.989	1.006	1.006
Vitamin and trace mineral premix	0.250	0.250	0.250	0.250	0.250	0.250	0.250
DL-methionine 98.5%	0.204	0.235	0.235	0.250	0.250	0.264	0.264
Salt, plain (NaCl)	0.190	0.167	0.167	0.129	0.129	0.090	0.090
Sodium bicarbonate	0.164	0.195	0.195	0.249	0.249	0.303	0.303
Phytase	0.008	0.008	0.008	0.008	0.008	0.008	0.008
L-lysine 78.8% (HCl)	0.004	0.070	0.070	0.070	0.070	0.070	0.070
L-isoleucine	0.001	0.043	0.043	0.048	0.048	0.053	0.053
L-valine	0.000	0.047	0.047	0.059	0.059	0.070	0.070
L-threonine 98.5%	0.000	0.021	0.021	0.029	0.029	0.037	0.037
Almond hulls	0.000	5.000	5.000	10.000	10.000	15.000	15.000
Enzyme	0.000		0.015		0.015		0.015
Calculated composition (%)							
Dry matter	88.7649	89.0923	89.0923	89.5003	89.5003	89.9083	89.9083
Crude protein	14.683	13.8962	13.8962	13.8453	13.8453	13.7943	13.7943
Crude fat	4.9085	6.2445	6.2445	7.9324	7.9324	9.6202	9.6202
Crude fiber	2.9835	3.5752	3.5752	4.1954	4.1954	4.8156	4.8156
Calcium	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Available phos.	0.43	0.43	0.43	0.43	0.43	0.43	0.43
M.E. (kcal/lb)	1,270.00	1,270.00	1,270.00	1,270.00	1,270.00	1,270.00	1,270.00
Digestible lysine	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Digestible methionine	0.4105	0.4253	0.4253	0.4318	0.4318	0.4383	0.4383
Digestible threonine	0.4792	0.462	0.462	0.462	0.462	0.462	0.462
Digestible tryptophan	0.1604	0.1478	0.1478	0.1468	0.1468	0.1458	0.1458
Digestible valine	0.5808	0.5808	0.5808	0.5808	0.5808	0.5808	0.5808
Digestible isoleucine	0.528	0.528	0.528	0.528	0.528	0.528	0.528

Results: Layer 1

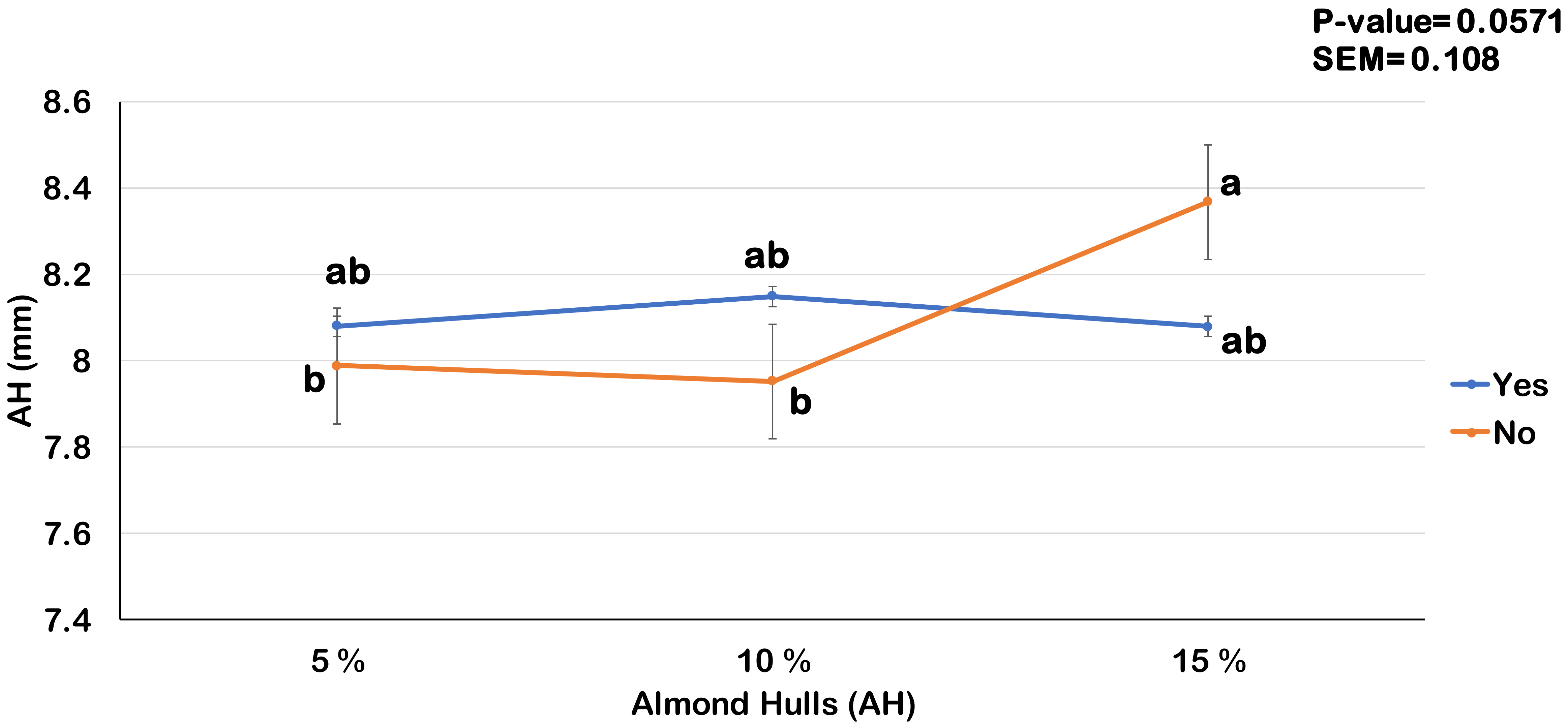
Almond Hulls x Enzyme
Hen day egg production (HDEP, %)

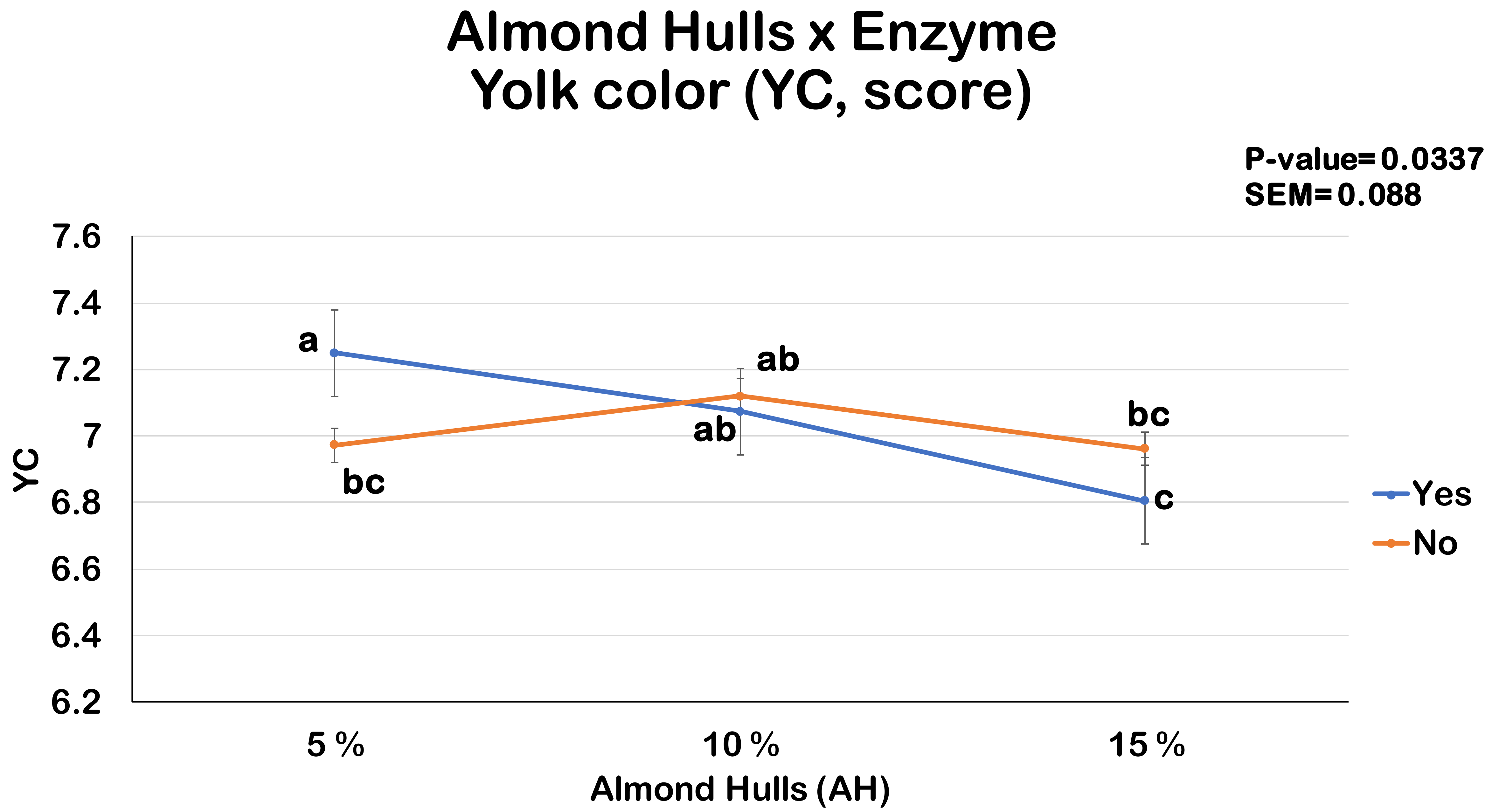




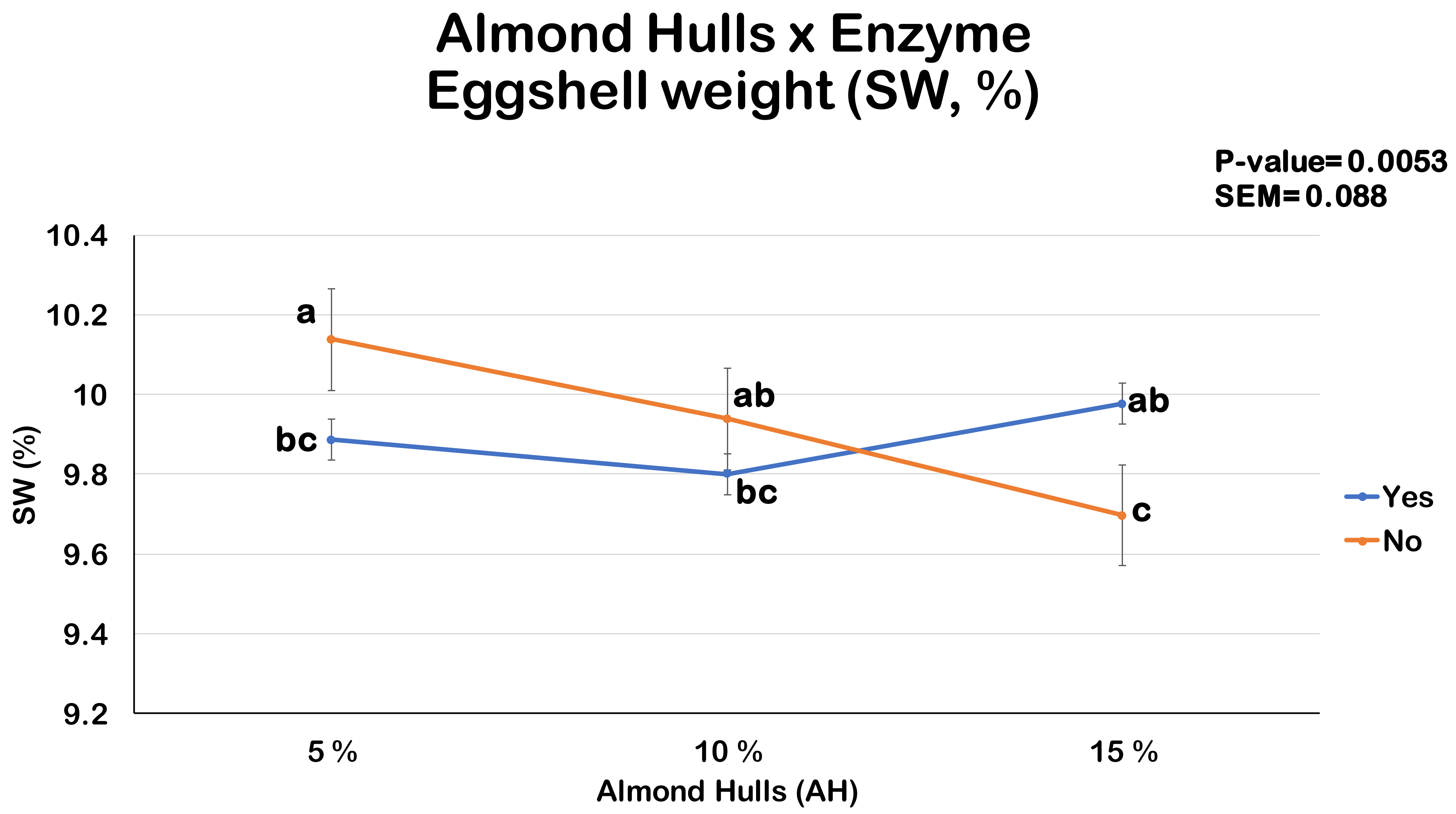
Almond Hulls x Enzyme
Egg Weight (EW, g)
P-value= 0.0392
SEM= 0.382
58.5
58
57.5
57
56.5
56
55.5
55
54.5
54
53.5
53
EW (g)
a
a
ab
bc
bc
c
5 %
10 %
15 %
Almond Hulls (AH)
Yes
No

Almond Hulls x Enzyme
Albumen Height (AH, mm)

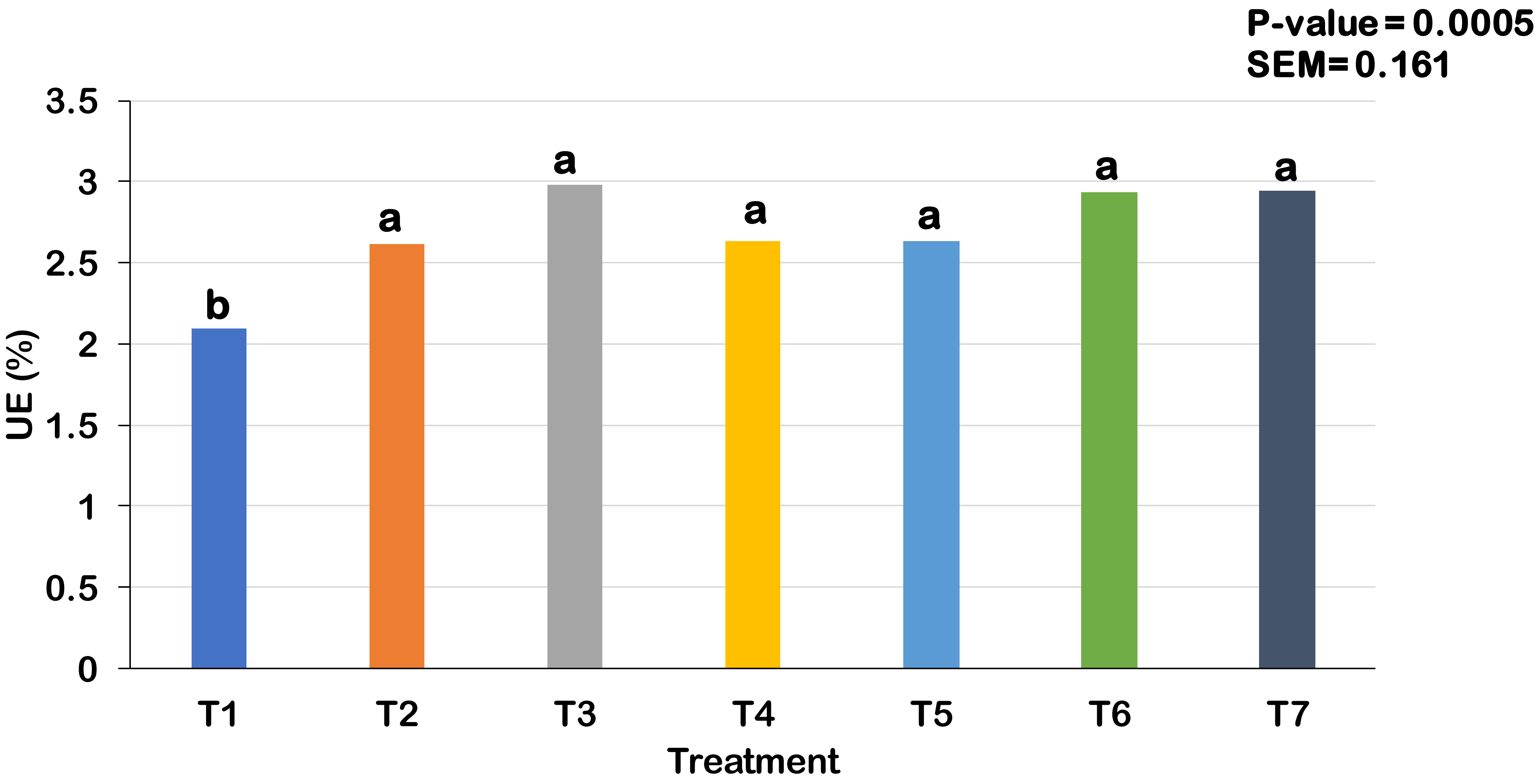




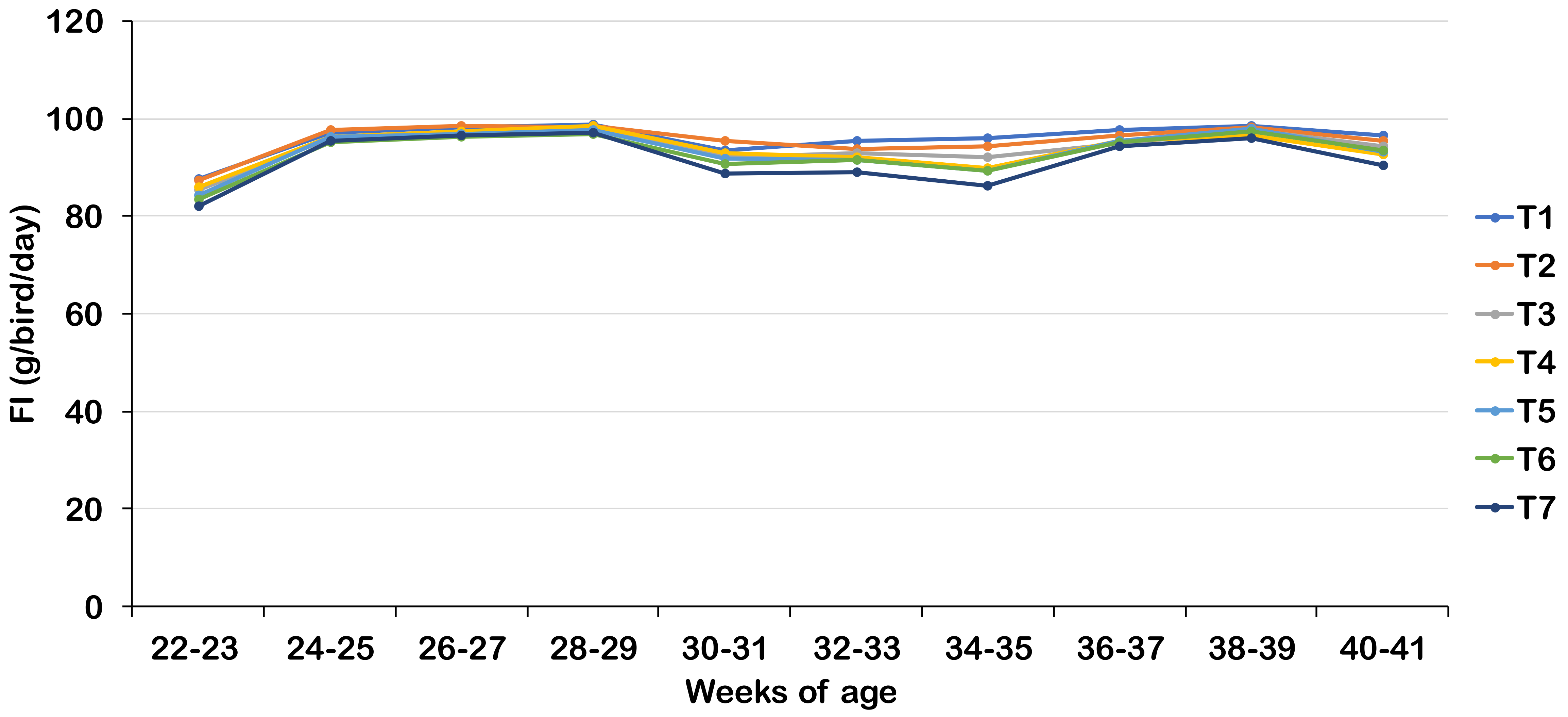
Almond Hulls x Enzyme
Yolk color (YC, score)
P-value= 0.0337
SEM= 0.088
YC
7.6
7.4
7.2
7
6.8
6.6
6.4
6.2
a
ab
ab
bc
bc
c
5 %
10 %
15 %
Almond Hulls (AH)
Yes
No



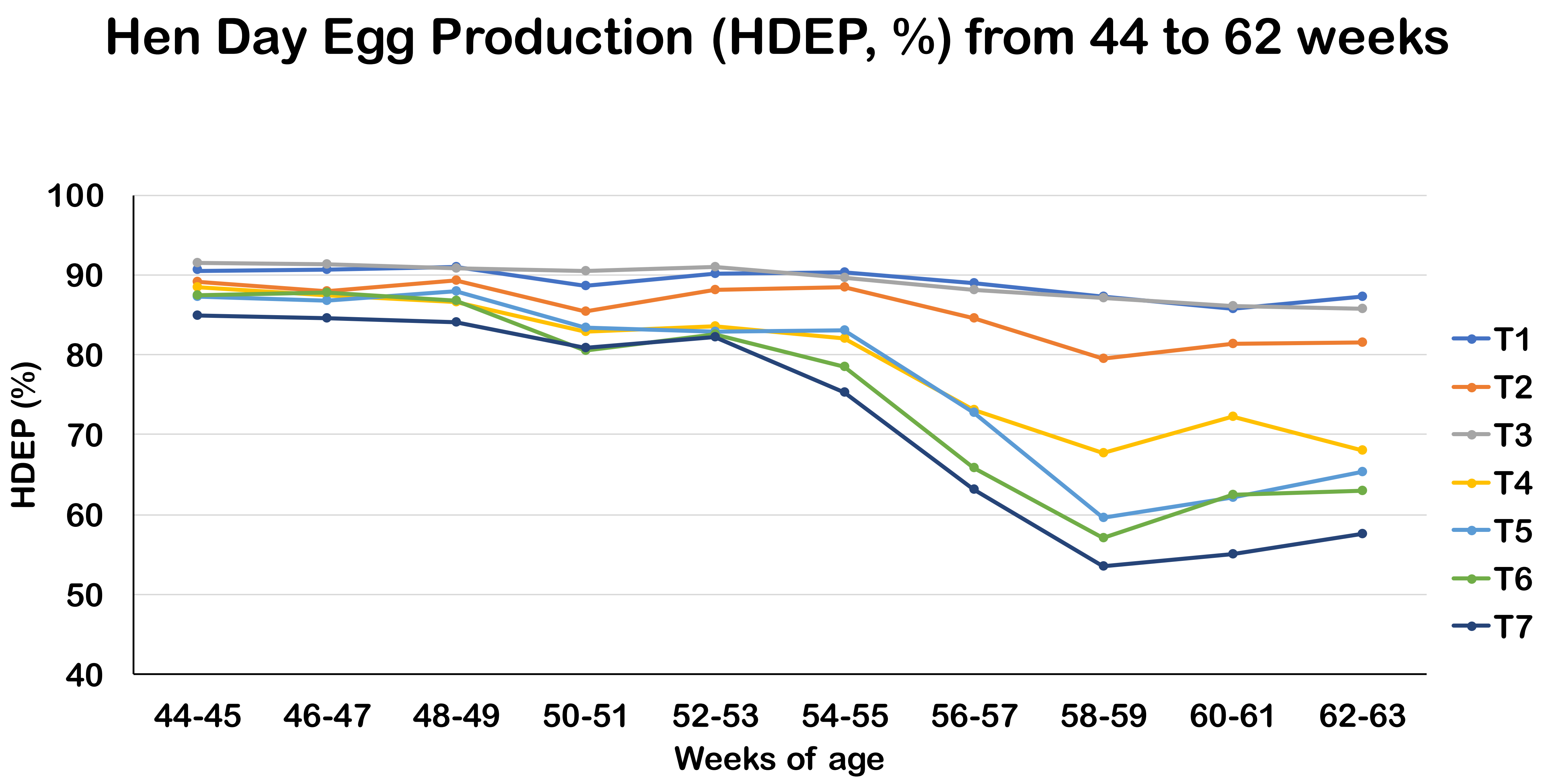
Almond Hulls x Enzyme
Eggshell weight (SW, %)
P-value= 0.0053
SEM= 0.088
10.4
10.2
10
9.8
9.6
9.4
9.2
SW (%)
a
bc
ab
bc
ab
c
Yes
No
5 %
10 %
15 %
Almond Hulls (AH)


P-value= 0.0005
SEM= 0.161
UE (%)
3.5
3
2.5
2
1.5
1
0.5
0
b
a
a
a
a
a
a
T1
T2
T3
T4
T5
T6
T7
Treatment

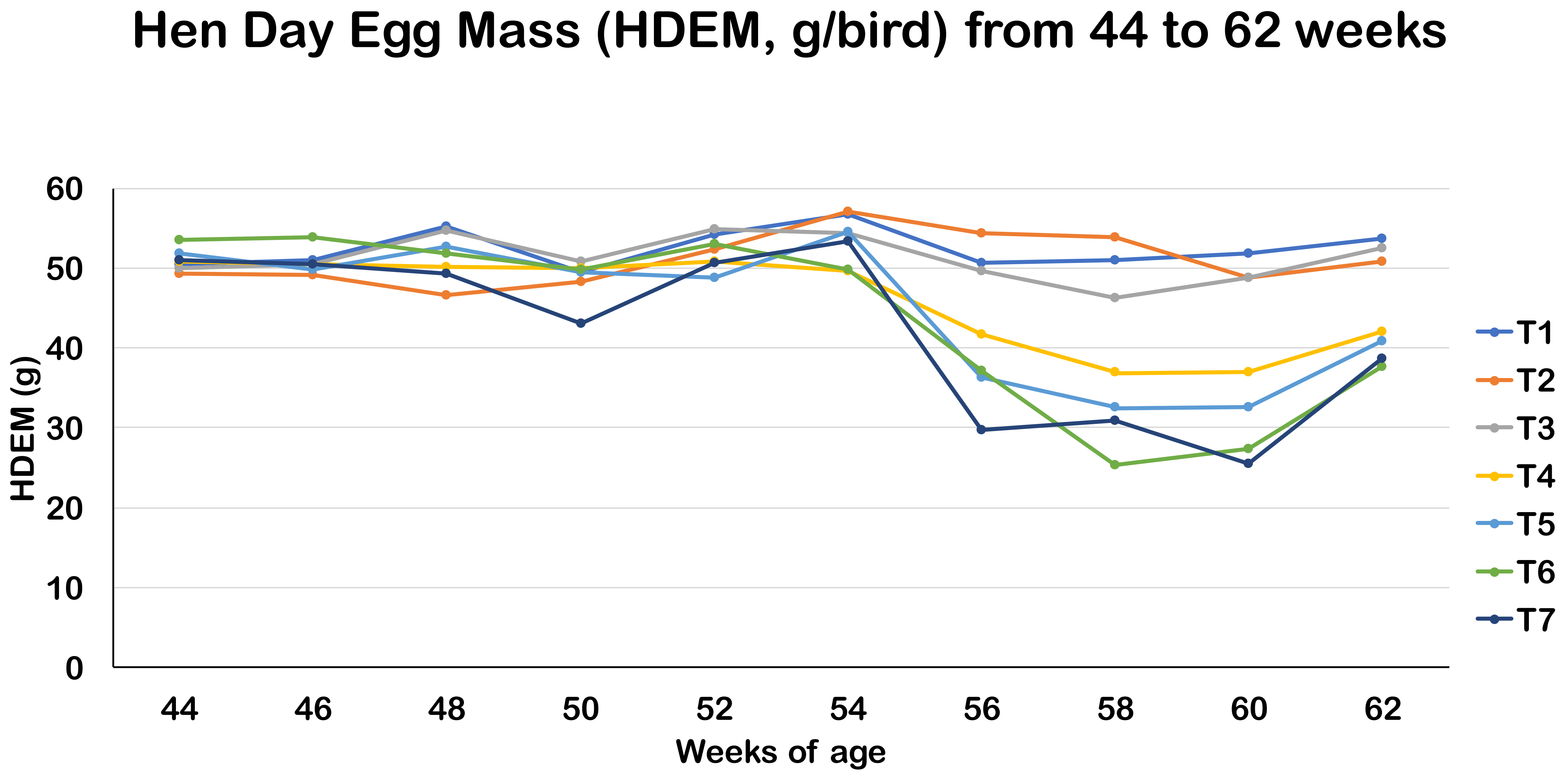
Feed Intake (FI, g/bird/day) from 22 to 41 weeks



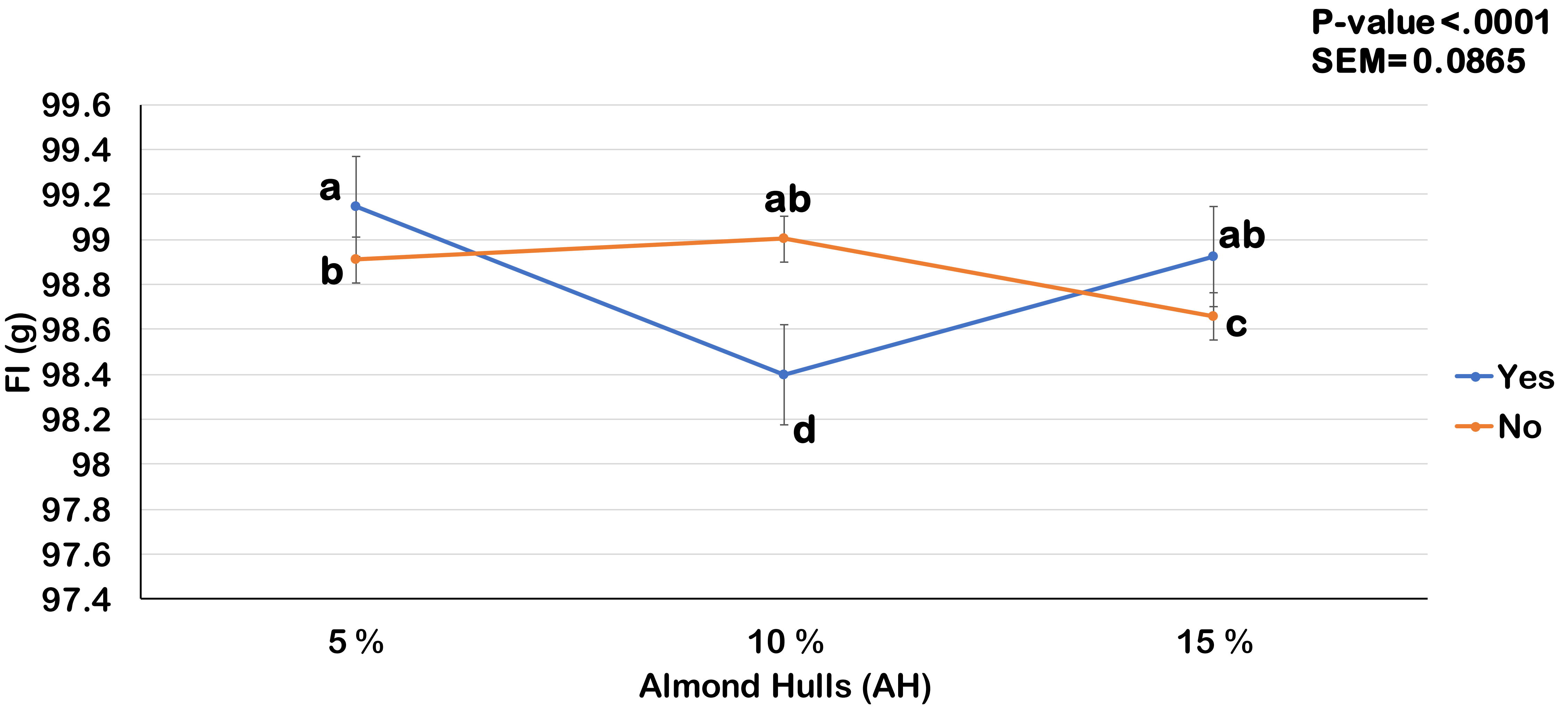
Results: Layer 2

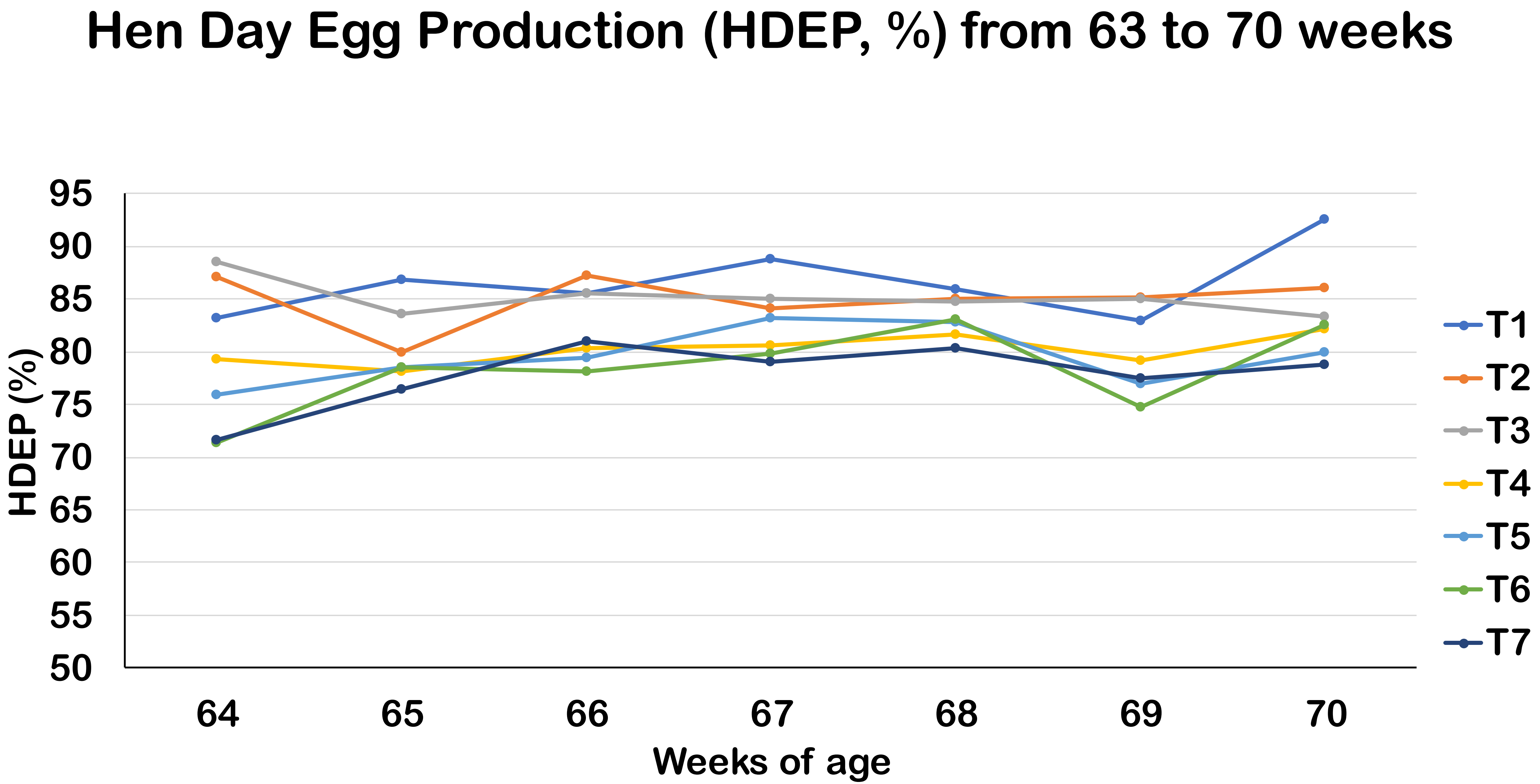


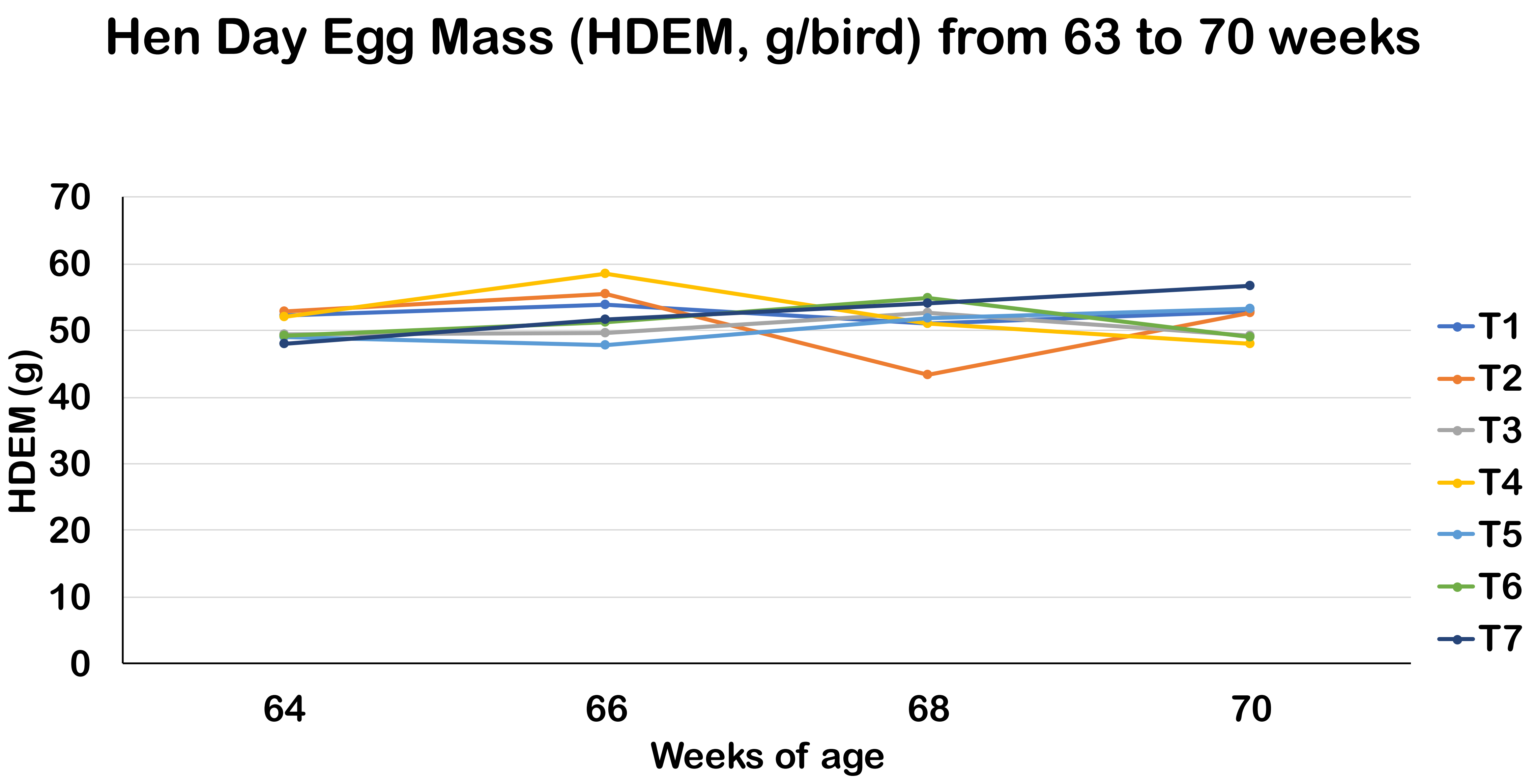
Hen Day Egg Production (HDEP, %) from 44 to 62 weeks
HDEP (%)
100
90
80
70
60
50
40
44-45
46-47
48-49
50-51
52-53
54-55
56-57
58-59
60-61
62-63
Weeks of age
T1
T2
T3
T4
T5
T6
T7


Hen Day Egg Mass (HDEM, g/bird) from 44 to 62 weeks
HDEM (g)
0
10
20
30
40
50
60
44
46
48
50
52
54
56
58
60
62
Weeks of age
T1
T2
T3
T4
T5
T6
T7

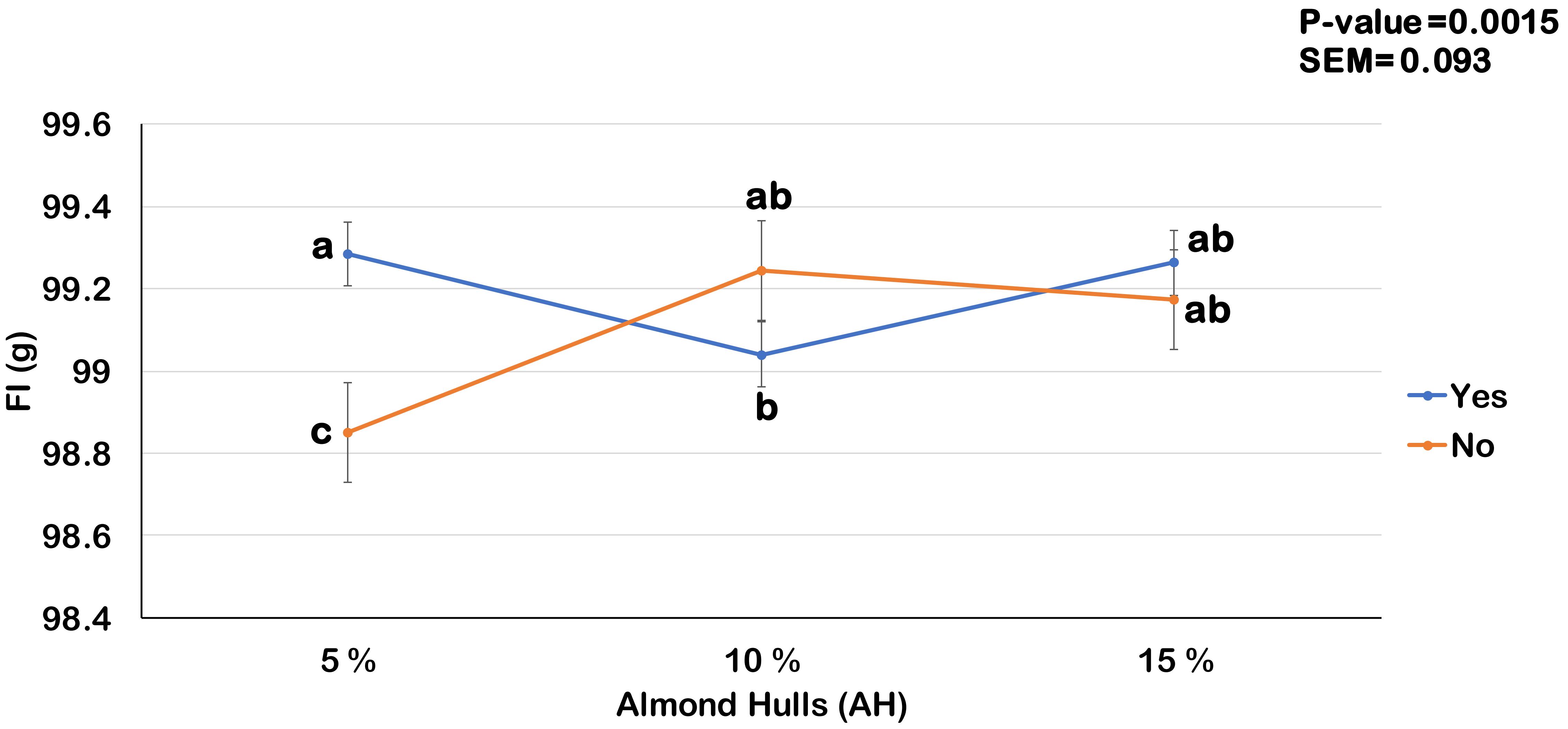
Almond Hulls x Enzyme
Feed Intake (FI, g/bird, day) 44-62 weeks

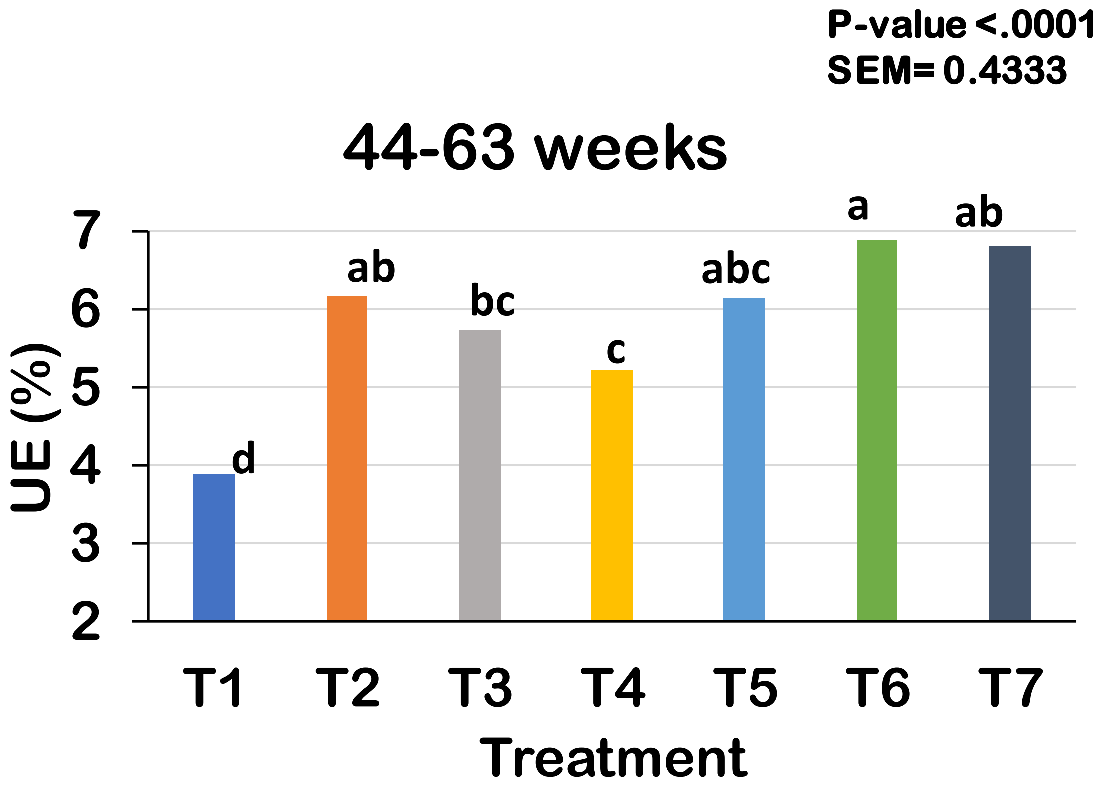


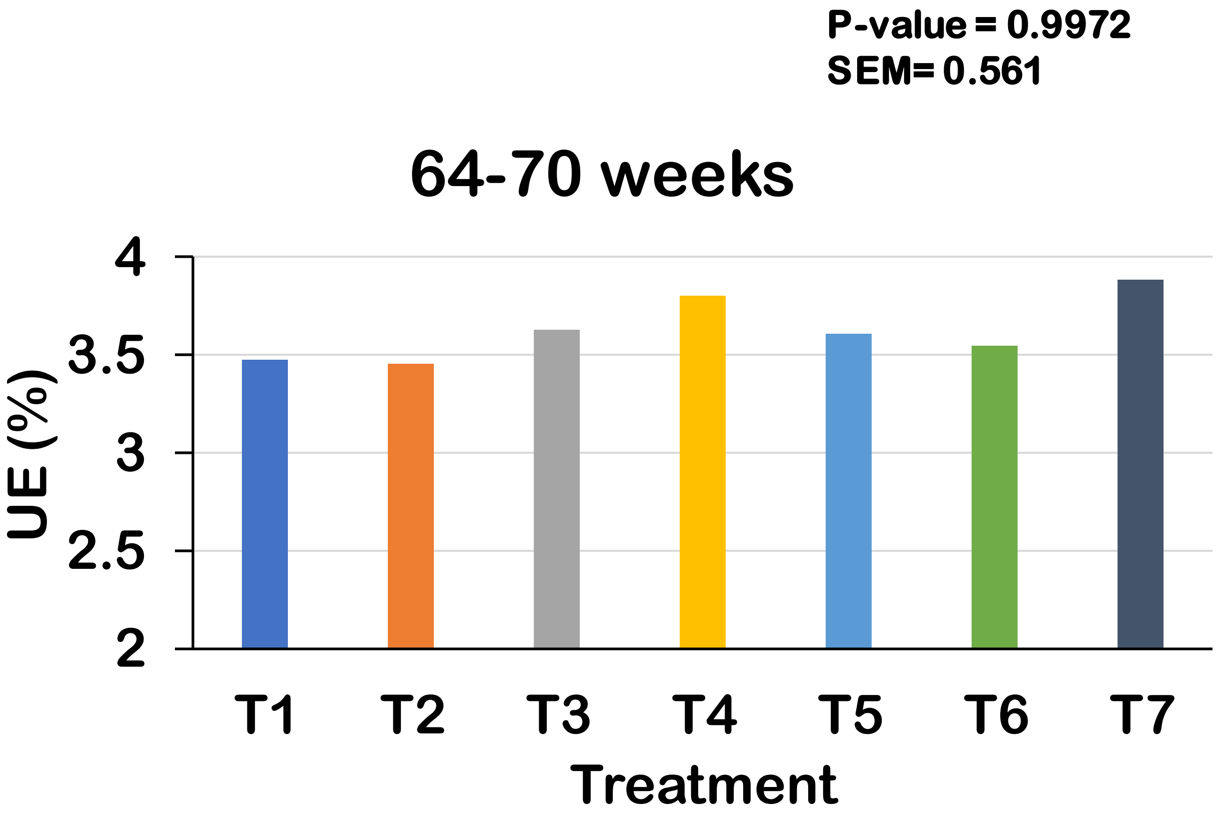

Hen Day Egg Production (HDEP, %) from 63 to 70 weeks
HDEP (%)
95
90
85
80
75
70
65
60
55
50
64
65
66
67
68
69
70
Weeks of age
T1
T2
T3
T4
T5
T6
T7


Hen Day Egg Mass (HDEM, g/bird) from 63 to 70 weeks
HDEM (g)
0
10
20
30
40
50
60
70
64
66
68
70
Weeks of age
T1
T2
T3
T4
T5
T6
T7

Almond Hulls x Enzyme
Feed Intake (FI, g/bird, day) 63-70 weeks




P-value <.0001
SEM= 0.4333
44-63 weeks
UE (%)
7
6
5
4
3
2
d
ab
bc
c
abc
a
ab
T1
T2
T3
T4
T5
T6
T7
Treatment


P-value = 0.9972
SEM= 0.561
64-70 weeks
UE (%)
4
3.5
3
2.5
2
T1
T2
T3
T4
T5
T6
T7
Treatment

Feed cost comparison at different price of AH $/ton

Feed cost $/US ton and AH $/ton	Feed cost $/US ton						
	T 1	T 2 5% AH	T 3 5% AH + E	T 4 10% AH	T 5 10% AH + E	T 6 15% AH	T 7 15% AH + E
Grower $120	$452.04	$449.46	$450.68	$456.64	$457.86	$463.82	$465.05
Grower $160	$452.04	$450.66	$451.88	$459.04	$460.26	$467.42	$468.65
Grower $280	$452.04	$454.26	$455.48	$466.24	$467.46	$478.22	$479.45
Developer $120	$490.38	$473.32	$474.55	$473.80	$474.92	$478.06	$478.90
Developer $160	$490.38	$474.52	$475.75	$476.20	$477.32	$481.66	$482.50
Developer $280	$490.38	$478.12	$479.35	$483.40	$484.52	$492.46	$493.30

	T 1	T 2 5% AH	T 3 5% AH + E	T 4 10% AH	T 5 10% AH + E	T 6 15% AH	T 7 15% AH + E
Layer 1 $120	$498.55	$506.70	$507.92	$520.26	$521.48	$533.81	$ 535.03
Layer 1 $160	$498.55	$508.70	$509.92	$ 524.26	$ 525.48	$ 539.81	$ 541.03
Layer 1 $280	$498.55	$514.70	$515.92	$ 536.26	$537.48	$557.81	$559.03
Layer 2 (Fat energy balance)$120	$548.28	$ 553.49	$554.72	$562.29	$563.51	$ 571.08	$572.31
Layer 2 (Fat energy balance)$160	$548.28	$555.49	$556.72	$566.29	$567.51	$577.08	$578.31
Layer 2 (Fat energy balance)$280	$548.28	$561.49	$562.72	$ 578.29	$579.51	$595.08	$596.31
Layer 2 (AH energy)$120	$550.75	$536.99	$538.21	$520.53	$521.76	$501.28	$502.50
Layer 2 (AH energy)$160	$550.75	$ 538.99	$540.21	$ 524.53	$ 525.76	$507.28	$508.50
Layer 2 (AH energy)$280	$550.75	$544.99	$546.21	$536.53	$537.76	$525.28	$526.50

Summary

- Throughout the peak lay age (22 and 41 weeks), feeding a diet with 10-15% almond hulls can increase production and egg weight, albumen height with better FCR and feed intake.

- Throughout the post-peaking age (42-70), the use of 5% AH in combination with the enzyme had a positive effect on egg production and FCR when the diets were formulated iso-calorically.
  - Hens fed the diet with 15% AH ate less feed compared to the other groups.
- 10% AH with enzyme together improved only egg weight
- 5% hulls was cheapest at each calculated at different prices of hulls

Conclusions

- It is recommended to feed upto 15% hulls without any negative effects on the production in peaking age layers.
- It is recommended to feed upto 5% hulls without any negative effects on the production in late- laying age layers.
- As hulls increased, the yolk color score was lowered suggesting corn was replaced more by hulls (corn giving xanthophylls).
- When we balance the energy with fat, the unsaleable eggs were reduced in all hulls fed hens.
- Thus, it is not recommended to feed hens without meeting their energy requirement; may not be solely depends on hulls for energy.

What next?

- Finding ways to increase the digestibility of amino acids and energy of the hulls – how?
  - Protease or any other types of energy digestibility works
- Using the prime-type (better) hulls and see what changes with the similar inclusion levels

Connecting the Dots 2023

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Digestibility valúes from - Dr. Adam Davis Lab

california almonds
Almond Board of California

Thank you

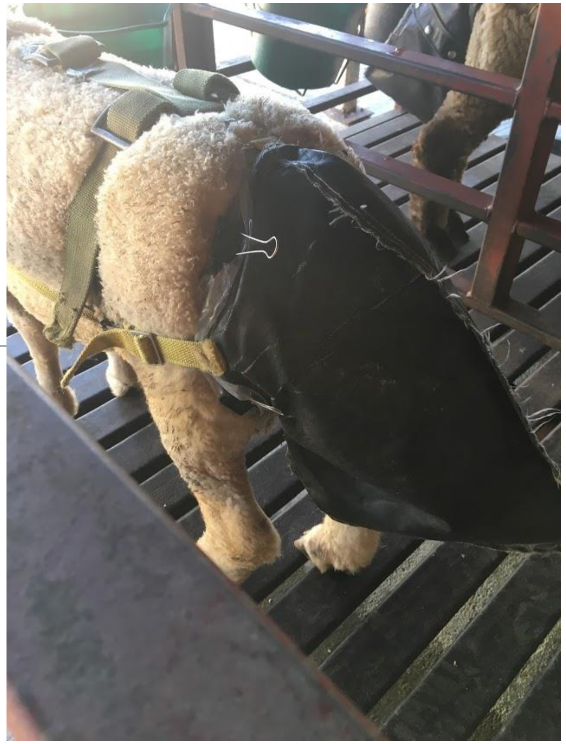
Development of New Alfalfa Products in Combination with Almond Hulls for Emerging Domestic and International Markets

KATHERINE SWANSON, HERNÁN RODRIGUEZ, ED DEPETERS, AND DAN PUTNAM

UNIVERSITY OF CALIFORNIA, DAVIS

Background

- The idea was that different combinations of alfalfa and almond hulls would utilize the strengths of each product, potentially producing a 'synergy' in combination, and could develop new products that open up new markets for almond hulls.
- From previous in vitro and in vivo work, we found that mixing low amounts of almond hulls with Low to Medium (e.g. 38-48% NDF) quality alfalfa hay could be beneficial by increasing the overall DM and CP digestibility with only slight decreases in fiber digestibility.



Summary Digestibility
% Apparent Total Tract from 2019 study

Item	0 lb AH	4 lb AH	8 lb AH	12 lb AH
DM, %	69.1	72.8	72.2	75.1
aNDF, %	47.5	51.4	49.0	52.9
aNDFom,%	47.9	52.6	50.5	51.6
ADF, %	41.6	43.5	43.4	46.9
ADFom, %	42.2	44.2	43.1	46.4
CP, %	66.2	68.1	66.8	70.0

DM, OM, and ADF all improved as more almond hulls were added

Objective

To evaluate the apparent digestibility, palatability, and effect on production in dairy cattle of alfalfa-almond hull cubed mixes compared with pure alfalfa cubes to help develop innovative products centered upon alfalfa and almond hulls.

Methods

- For this study, medium quality alfalfa was cubed with 0, 20, or 30% almond hulls. Cows were fed a total mixed ration with the cubes added in.
- Six lactating multiparous and three lactating primiparous Holstein cows were fed three diets in a replicated 3x3 Latin square design study with three 21-day periods.

Methods

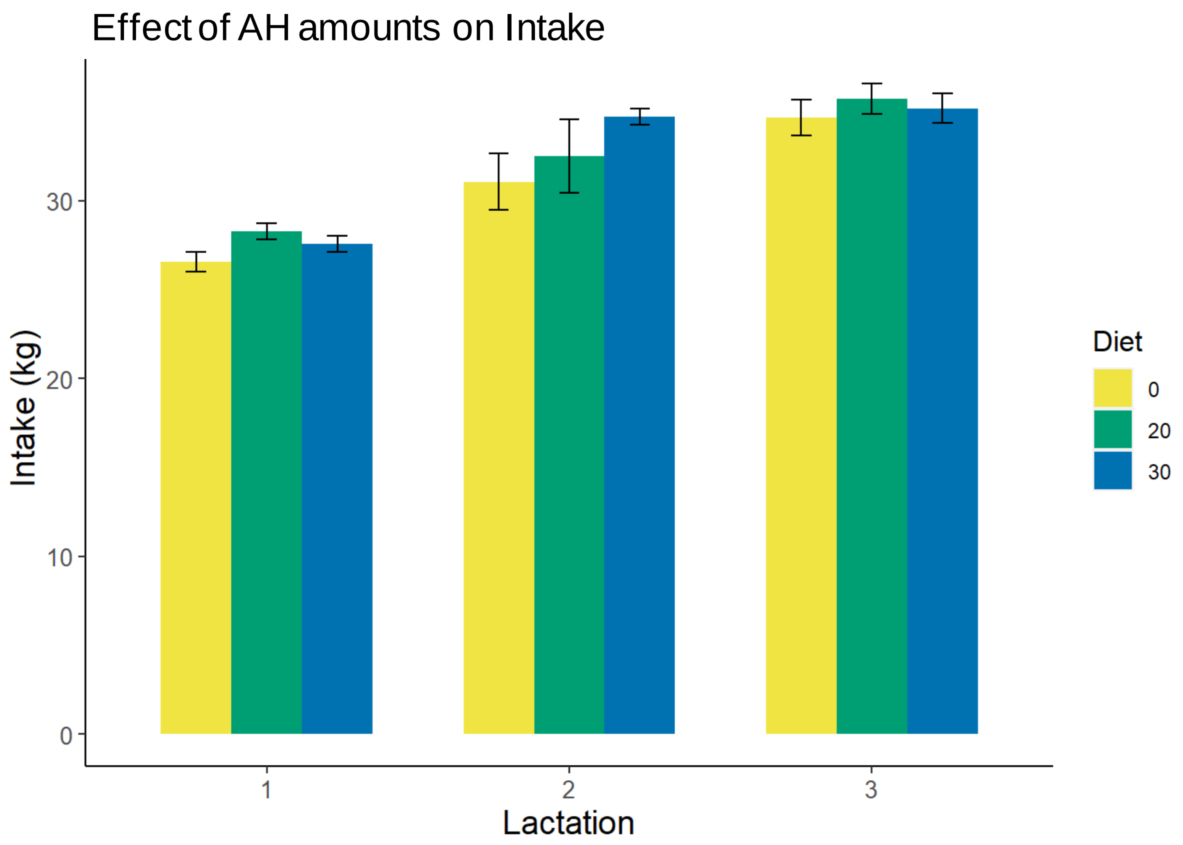
- Cows were milked and fed twice daily with milk yield and feed intake recorded daily for each cow to determine intake and production
- Feed refusals, fecal, blood, milk, and rumen fluid samples were also collected along with weekly body weights. This was used to estimate digestibility, milk composition, ketone concentration, and volatile fatty acid concentration.
- Data were analyzed using R and a linear mixed effects model.

Results - Diet Composition

Feed Composition of Diets on %Dry Matter Basis						
%AH	0%	SD	20%	SD	30%	SD
CP	16.7	0.60	16.4	0.06	17.8	0.15
ADFom	21.6	0.10	22.0	0.90	20.8	0.76
NDFom	30.3	1.17	29.6	0.46	27.8	0.38
Lignin	3.04	0.07	3.91	0.12	3.68	0.36
Starch	24.7	1.50	23.1	1.45	22.3	0.87
Fat	3.61	0.34	3.59	0.41	4.12	0.83
Ash	7.44	1.11	7.38	1.21	8.17	0.80
ESC	5.67	0.12	6.87	0.45	7.20	0.36
WSC	8.87	0.38	10.5	0.40	9.70	0.10
NFC	43.3	2.95	44.0	0.21	43.3	1.23
NSC	30.3	1.46	29.9	1.75	29.5	0.60
NEL (Mcal/lb)	0.74	0.02	0.73	0.01	0.74	0.01

Intake

- No consistent trend
- Dry matter and ADF highest for 20% AH
- Crude protein highest for 30% AH
- NDF lowest for 30% AH



Apparent Digestibility Percentage						
% AH	0%	20%	30%	SE	Linear	Quadratic
DM	65.3	62.0	64.1	0.9	0.14	0.003
CP	65.9	60.2	64.7	1.0	0.19	0.001
ADF	42.4	40.2	43.3	1.4	0.42	0.013
NDF	43.7	35.8	39.9	2.1	0.16	0.018

Time spent ruminating was significant for diet and period and there was a significant overall quadratic effect. This meant that the cows consuming the 20% AH cube diet spent the most amount of time ruminating (448 minutes/day), while those consuming the 30% AH diet spent the least amount of time (430 minutes/day).

Milk Yield and Composition				
% AH	0%	20%	30%	SE
Yield (kg/day)				
Milk	46.0	45.7	45.1	2.37
ECM	46.4	47.5	46.7	1.76
Fat	1.51	1.60	1.58	0.06
Protein	1.54	1.55	1.51	0.07
Lactose	2.34	2.31	2.27	0.13
Composition %				
Fat	3.31	3.55*	3.48	0.19
Protein	3.37	3.40	3.35	0.07
Lactose	5.07	5.05	5.05	0.05
MUN	8.95	8.76	9.94*	0.29
SCC	19.4	19.8	24.8	6.5

Volatile Fatty Acid Concentrations				
% AH	0%	20%	30%	SE
VFA's (mmol/L)				
Acetate	41.7	44.3	42.6	2.5
Propionate	18.6	19.0	18.5	1.35
Butyrate	5.83	7.44	6.48	0.74

No consistent trend amongst cows and diets. Numerical difference in averages, but not significant.

Overall

- Cows consumed the most CP, NDF, and ADF while on the 20% AH cube diet, but had the lowest digestibilities for those components.
- This diet also resulted in the most time spent ruminating and the highest amount (numerically) of ECM, protein, and fat production.
- The milk fat percentage was highest for the cows consuming the 20% AH cube diet as well.
- This research suggests that mixing low amounts of almond hulls with medium (e.g. 38% NDF) quality alfalfa hay could be beneficial by increasing the milk fat composition and yield of high producing dairy cows compared with cows consuming no almond hulls.

Acknowledgements

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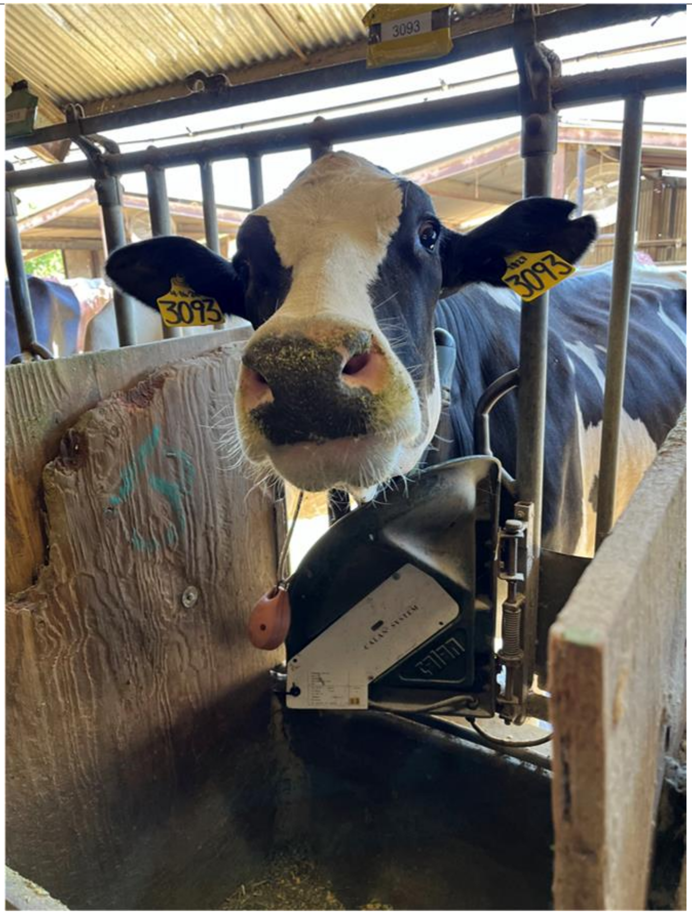
- We would also like to thank the UC Davis dairy employees and the undergraduate student employees that helped make this project possible.



Fermented Almond Hulls for Reducing Enteric Methane Emissions from Cattle

Ruihong Zhang[1], Matthias Hess[2], and Hamed El Mashad[1]
[1]Department of Biological and Agricultural Engineering
[2]Department of Animal Science
University of California, Davis

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Principal Investigators:

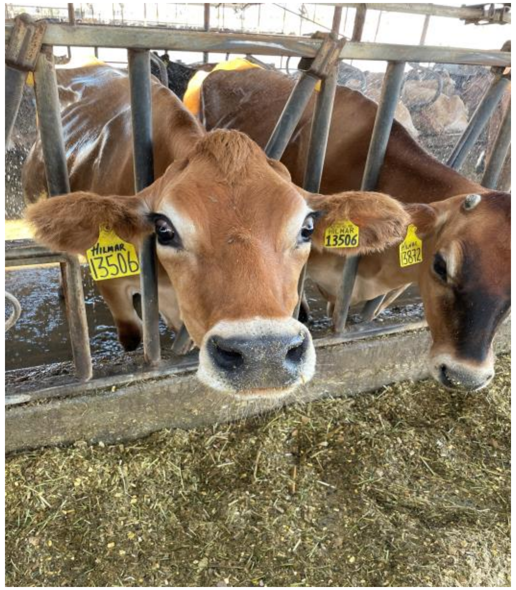
Ruihong Zhang, Matthias Hess, Hamed El Mashad, Ermias Kebreab and Zhongli Pan

Research Staff:

Emily Sechrist, Lin Cao, Allan Chio, Rich Duong

Almond Hulls as Cattle Feed

- High in sugar (25-42% DM)
- Rich in antioxidants (3-8%)
- Consumed already by 38% of CA dairy cattle (~3 lb/d/cow = 5% of diet)
- Can be fed up to 20% of the diet to lactating dairy cows:
  - Support milk production
  - Improve digestibility
  - Improve milk fat content



Fermented Feed

- Fermented feed has been mostly studied in pigs and chickens:
  - Improved performance and nutrient digestion in pigs
  - Recognized for reducing antibiotic use in pigs
  - Decreased mortality rates and improved immune responses in chickens
- Few studies on cattle fermented feed, but probiotic supplementation with yeast shows nutritional benefits and potential reduction in enteric methane emissions

https://www.kalmbachfeeds.com/blog/the-scoop-on-fermenting-chicken-feed/

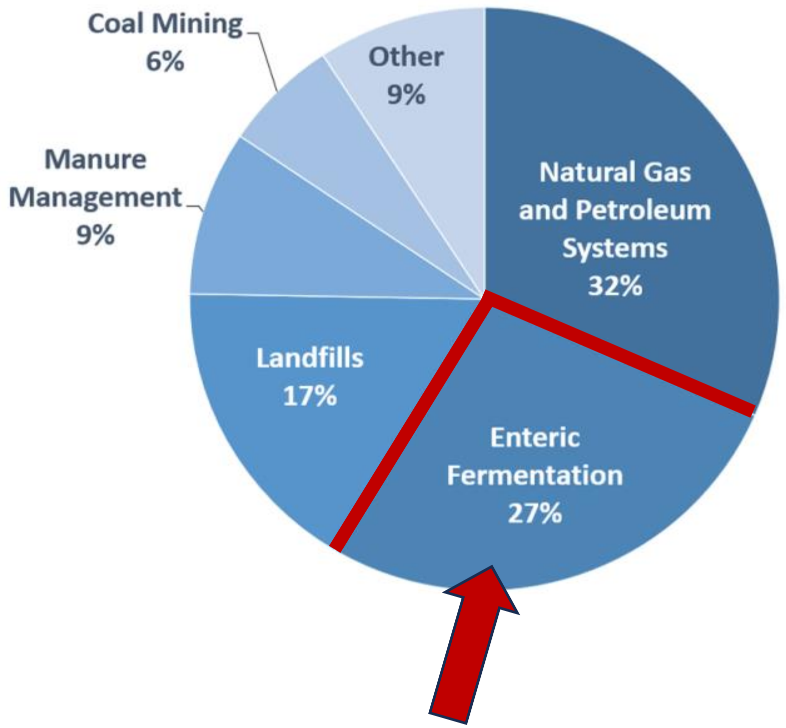
Methane Emission from Cattle

Why target enteric methane (CH_4)?

- 25% of CH_4 emissions in US attributed to enteric fermentation
- CA Senate Bill 1383 (2016)
  - Reduce CH_4 emissions by 2030: 40% below 2013 levels

Sources of Methane in US

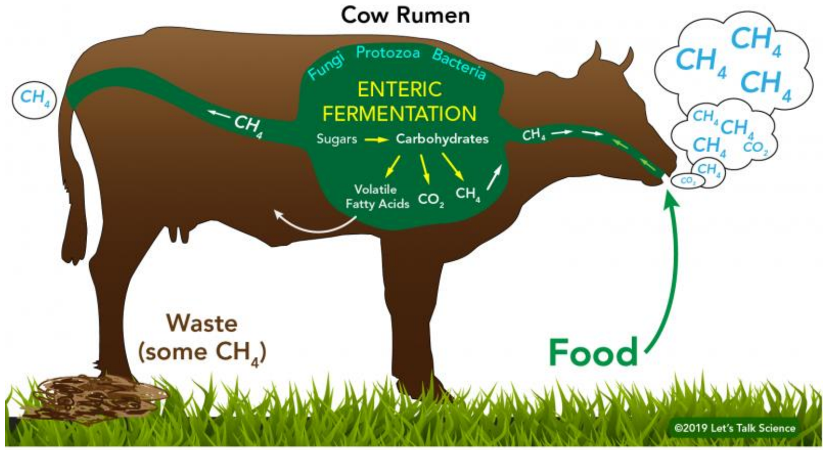
(*US EPA, 2020*)



¼ of all US CH_4

Reducing Enteric Methane Emission

- **Rumen modifiers:** modify the rumen environment limiting the growth of methanogens:
  - Saponins (AKA triterpene glycosides) and tannins
- **Rumen inhibitors:** act directly on the methanogenesis pathway by targeting methanogens specifically:
  - 3-nitrooxypropanol (3-NOP, marketed as Bovaer in the European Union)
  - Red seaweed *Asparagopsis taxiformis*



Will fermented almond hulls have anti-methanogenic properties?

Research Objectives

- Develop methods for producing high quality fermented feed from almond hulls

- Determine the anti-methanogenic and nutrition value of fermented almond hulls.

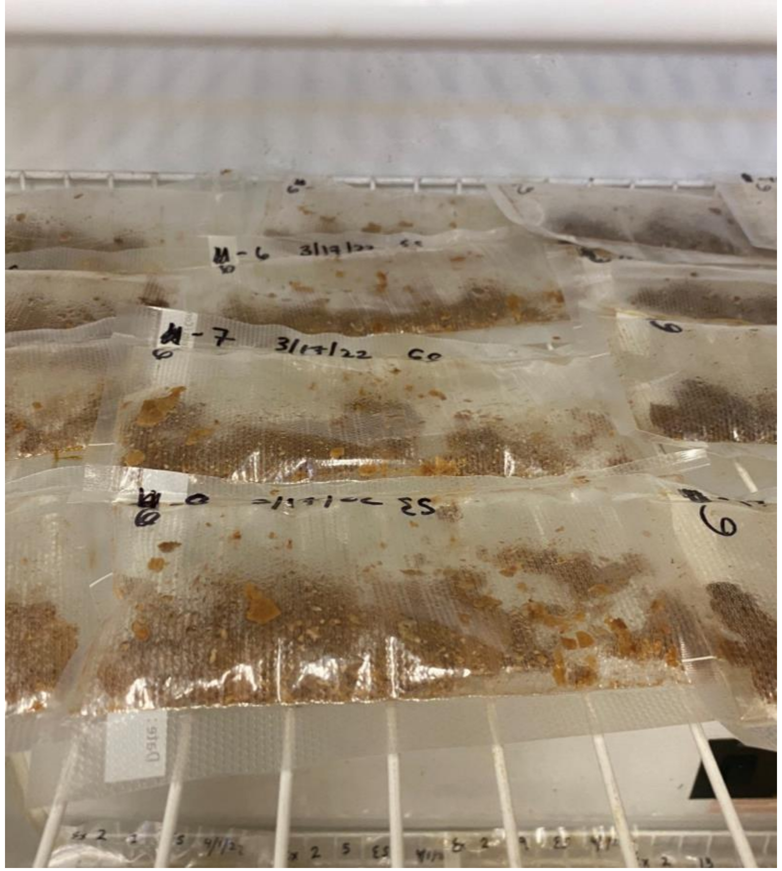
Almond Hulls

- Almond hulls : green, off-ground harvested

Variety	Sugar (% d.b.)	Phenolic compounds (tannic acid eqv, % d.b.)
Nonpareil	31.8%	5.5%
Monterey	33.1%	6.8%
Independence	42.2%	3.4%
Fritz	41.7%	7.6%

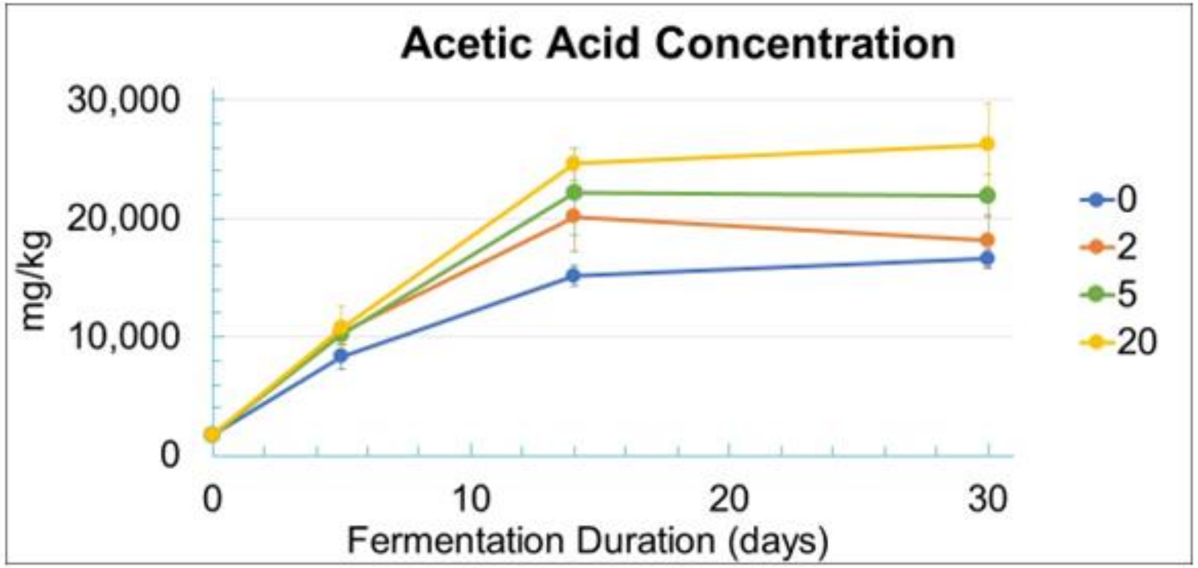
Fermenting Almond Hulls at Different Conditions

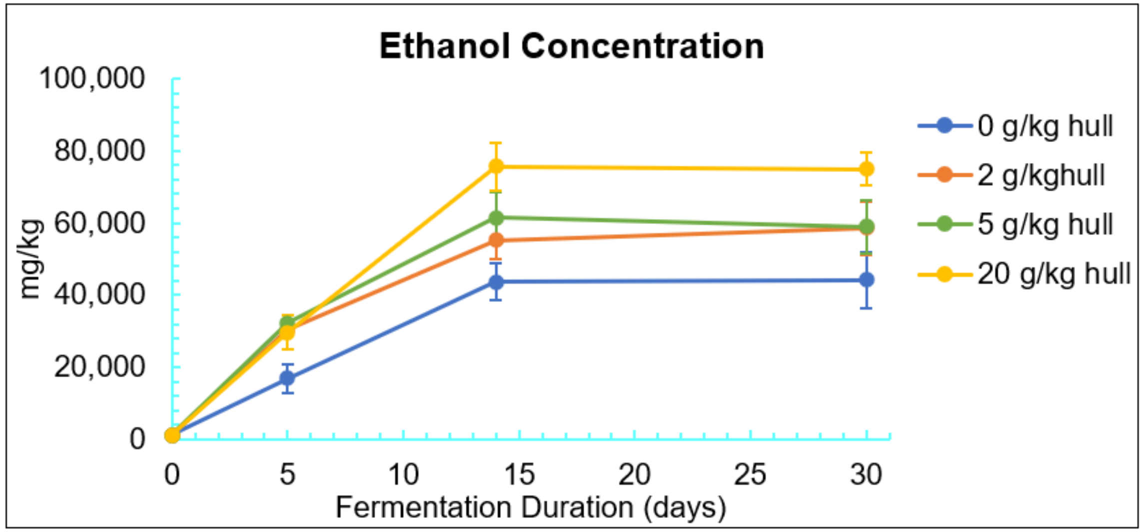
- Fermentation conditions
  - Different varieties
  - Whole and ground hulls
  - Microbial inoculum: Saccharomyces *cerevisiae* (0-20 g/kg)
  - Temperature: 25- 45 ^{o}C
  - Moisture content: 60%-70% (wet basis)
- Fermentation products
  - Organic acids: lactic acid and volatile fatty acids (acetic, propionic, butyric)
  - Alcohols: ethanol
  - pH

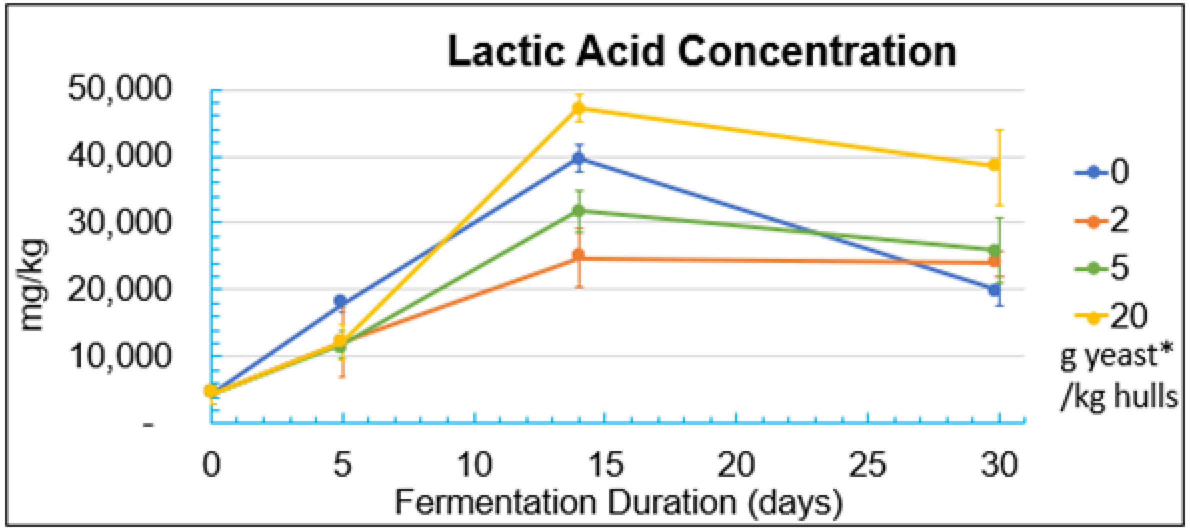


Fermentation of Almond Hulls

- ➢ Variety: Independence
- ➢ Fermentation conditions:
- Amount of yeast: 0-20 g yeast/kg hulls
- Fermentation times: 5-30 days
- Temperature: 40°C

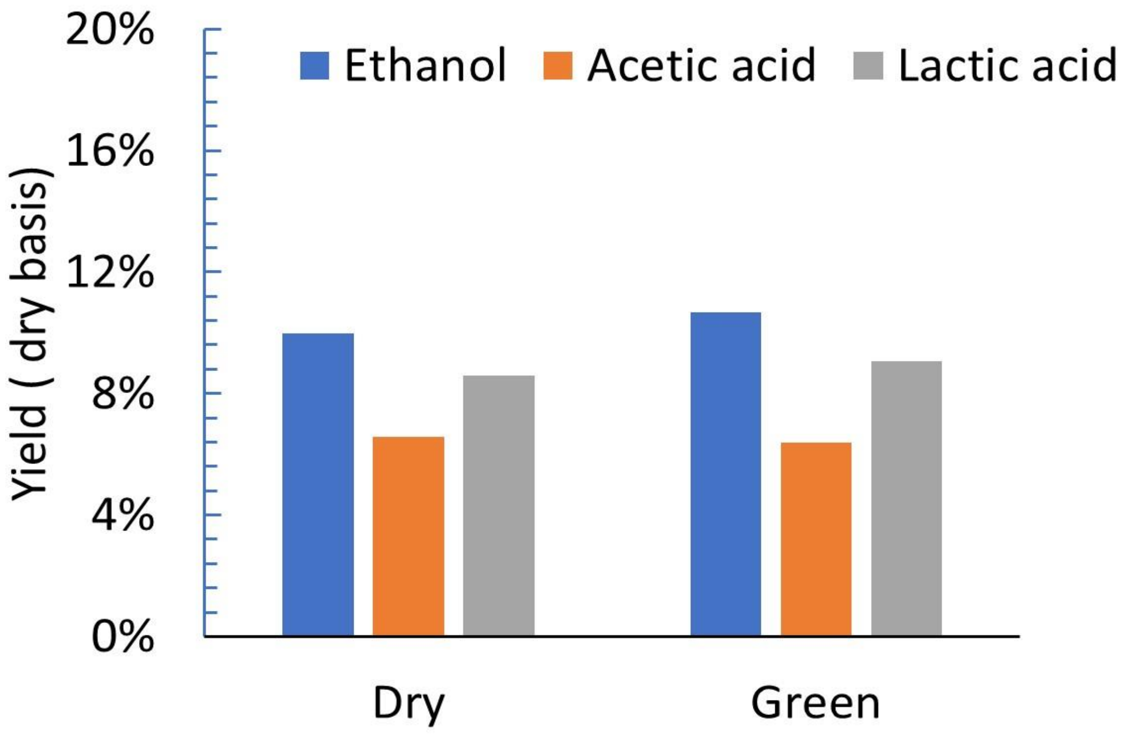






Fermentation of Dry and Green Almond Hulls

- Nonpareil variety, < 4.75 mm
- Fermentation conditions:
  - 35 ^{o}C temperature, 60% moisture, 10 g[yeast]/kg hulls



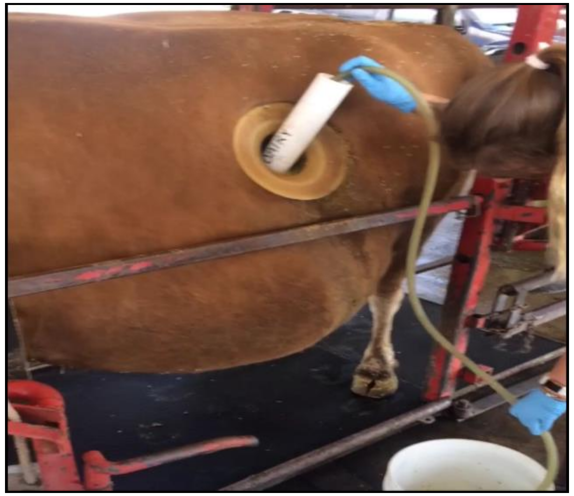
Dry Hulls from
On-Ground Harvesting

Green Hulls from
Off-Ground Harvesting

In-Vitro Rumen Fermentation

- Enables Economic & Reliable Evaluation of Rumen Response to Feed Modulation

  - Base Diet: Total Mixed Ration (TMR), traditional CA dairy feed
  - Hull Inclusion Rates: 20%
  - Rumen Incubation Duration: 72hr
  - Measurement: CH_4 and CO_2 Production



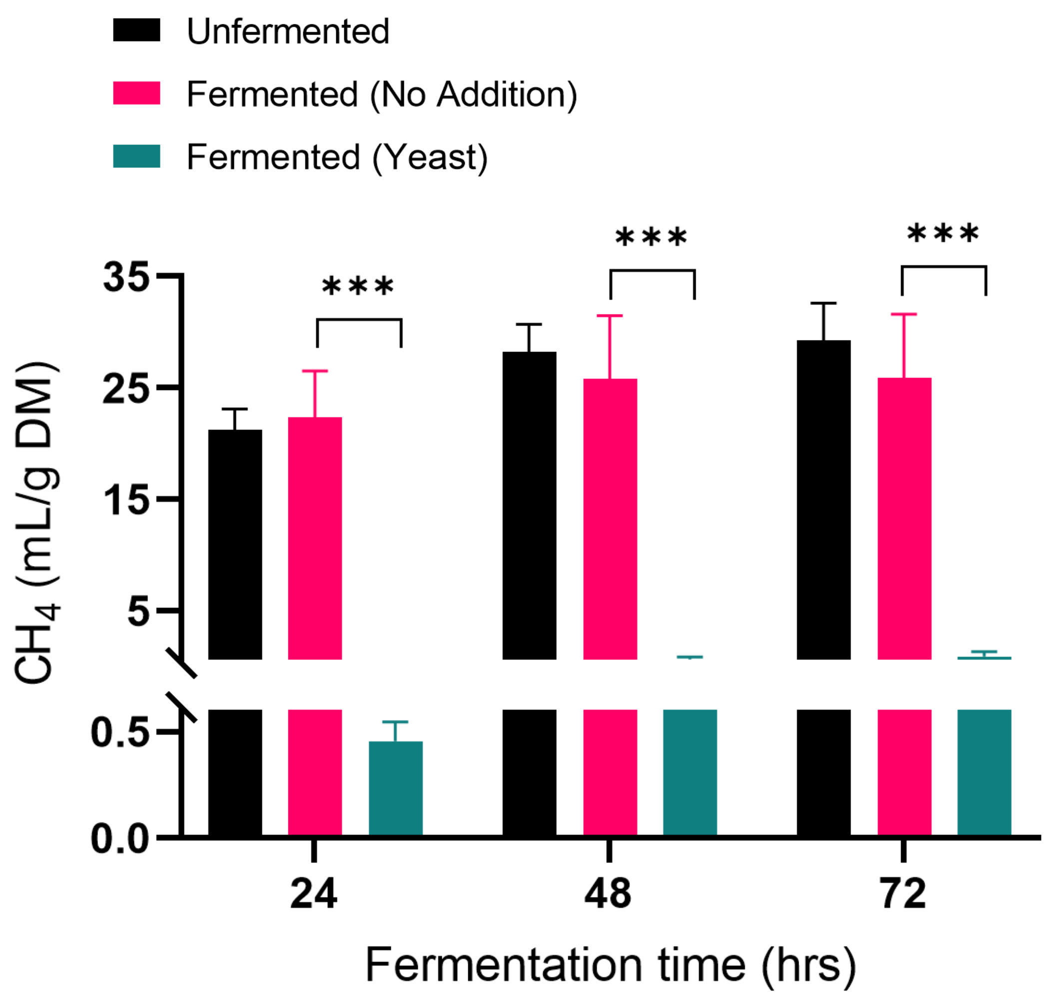
Collection of rumen fluid

In-Vitro test

In-Vitro Rumen Methane Production

- **Hulls:**
  - Fermented with yeast
  - Fermented without yeast
  - Unfermented

Finding: Yeast-fermented Hulls reduced CH_4 production by 96%



*** indicates significance p<0.0005; one-tailed t-test;

Conclusions

- Almond hulls fermented with Saccharomyces Cerevisiae for 14 days reduced enteric methane production by 96% over 72 hours digestion at a 20% inclusion rate in dairy cattle diet.
- Dry and green hulls produced fermented feed with similar characteristics (lactic acetic acids, and ethanol)
- Feeding cattle with fermented almond hulls is potentially an effective strategy to reduce enteric methane production while providing nutritional benefits.

Future Research Needs

- Scale-up fermentation processes and produce consistent and high-quality feed
- Conduct feeding trials with dairy and beef cattle to determine the proper inclusion rate in the cattle diet

Follow-up Research Projects

Current

- CDFA Specialty Crop Grant
  - Creating Nutritious and Highly Digestible Fermented Animal Feeds from Almond Hulls and Tomato Pomace

Pending (Livestock Enteric Methane Emission Reduction Research Program (LEMER-RP))

- CDFA Enteric Methane Reduction Grant
  - Demonstration of Fermented Agricultural Byproducts as Dietary Modulators to Reduce Enteric Methane Emission from Dairy Cows
  - Reducing Enteric Methane Emissions from Beef Cattle by Inclusion of Fermented Almond Hulls in a Typical California Feedlot Ration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Thank you