PETFOOD FORUM

Where the GLOBAL PET FOOD INDUSTRY does business

#petfoodforum

# Unraveling the myth of dietary carbohydrates and feline obesity: A meta-analysis and study findings

**H. Godfrey**, A.K. Shoveller, J.E. Ellis, & A. Verbrugghe

April 28-30, 2025, Kansas City, Missouri, USA

# Feline Obesity

**Excessive adipose tissue that can cause adverse health effects**

**Overweight in Domestic Cats Living in Urban Areas of Italy: Risk Factors for an Emerging Welfare Issue**

by Laura Arena [1], Laura Menchetti [1], Silvana Diverio [1,*], Giovanna Guardini [2], Angelo Gazzano [2] and Chiara Mariti [2]

[1] Laboratory of Ethology and Animal Welfare (LEBA), Department of Veterinary Medicine, Perugia University, 06126 Perugia, Italy
[2] Department of Veterinary Sciences, University of Pisa, 56124 Pisa, Italy
* Author to whom correspondence should be addressed.

*Animals* **2021**, *11*(8), 2246; **https://doi.org/10.3390/ani11082246**

ELSEVIER

The Journal of Nutrition
Volume 136, Issue 7, July 2006, Pages 1940S-1946S

## The Growing Problem of Obesity in Dogs and Cats [1, 2, 3]

German Alexander J

ELSEVIER

Preventive Veterinary Medicine
Volume 46, Issue 3, 10 August 2000, Pages 183-196

## A cross-sectional study of risk factors for obesity in cats in New Zealand

F.J Allan [a], D.U Pfeiffer [b], B.R Jones [c], D.H.B Esslemont [d], M.S Wiseman [e]

Öhlund *et al. Acta Vet Scand (2018) 60:5*
https://doi.org/10.1186/s13028-018-0359-7

Acta Veterinaria Scandinavica

RESEARCH Open Access

## Overweight in adult cats: a cross-sectional study

Malin Öhlund[1*], Malin Palmgren[2] and Bodil Ström Holst[1]

**Overweight in Domestic Cats Living in Urban Areas of Italy: Risk Factors for an Emerging Welfare Issue**

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ELSEVIER

Preventive Veterinary Medicine
Volume 107, Issues 1–2, 1 November 2012, Pages 121-133

## A cross-sectional study to compare changes in the prevalence and risk factors for feline obesity between 1993 and 2007 in New Zealand

N.J. Cave [a], F.J. Allan [a], S.L. Schokkenbroek [b], C.A.M. Metekohy [c], D.U. Pfeiffer [d]

Review > J Feline Med Surg. 2024 Feb;26(2):1098612X241228042.
doi: 10.1177/1098612X241228042.

## Identifying the target population and preventive strategies to combat feline obesity

Hannah Godfrey [1], Shawna Morrow [2], Sarah K Abood [2], Adronie Verbrugghe [2]

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## Prevalence and risk factors of obesity in an urban population of healthy cats

Laurence Colliard, Bernard-Marie Paragon, [...], and Géraldine Blanchard +2 View all authors and affiliations

All Articles | https://doi-org.subzero.lib.uoguelph.ca/10.1016/j.jfms.2008.07.002

Vet Med - Czech, 2016, 61(6):295-307 | DOI: 10.17221/145/2015-VETMED

## Feline obesity - prevalence, risk factors, pathogenesis, associated conditions and assessment: a review

Review

D. Tarkosova [1], M.M. Story [2], J.S. Rand [2], M. Svoboda [1]

# Risk Factors of Feline Obesity

**Feeding Practices**

Free-feeding
Feeding Frequency
Primarily dry food diets

**Cat Characteristics**

Sex
Neuter status
Breed
Genetics

**Environment**

Indoor confinement
Inactivity/Low
Enrichment

# Risk Factors of Feline Obesity

| Feeding Practices | Cat Characteristics | Environment |
|---|---|---|
| Free-feeding | Sex | Indoor confinement |
| ~~Feeding Frequency~~ | Neuter status | Inactivity/Low |
| **Primarily dry food diets** | Breed | Enrichment |
| | Genetics | |

# What is the link between feeding primarily dry foods and feline obesity?

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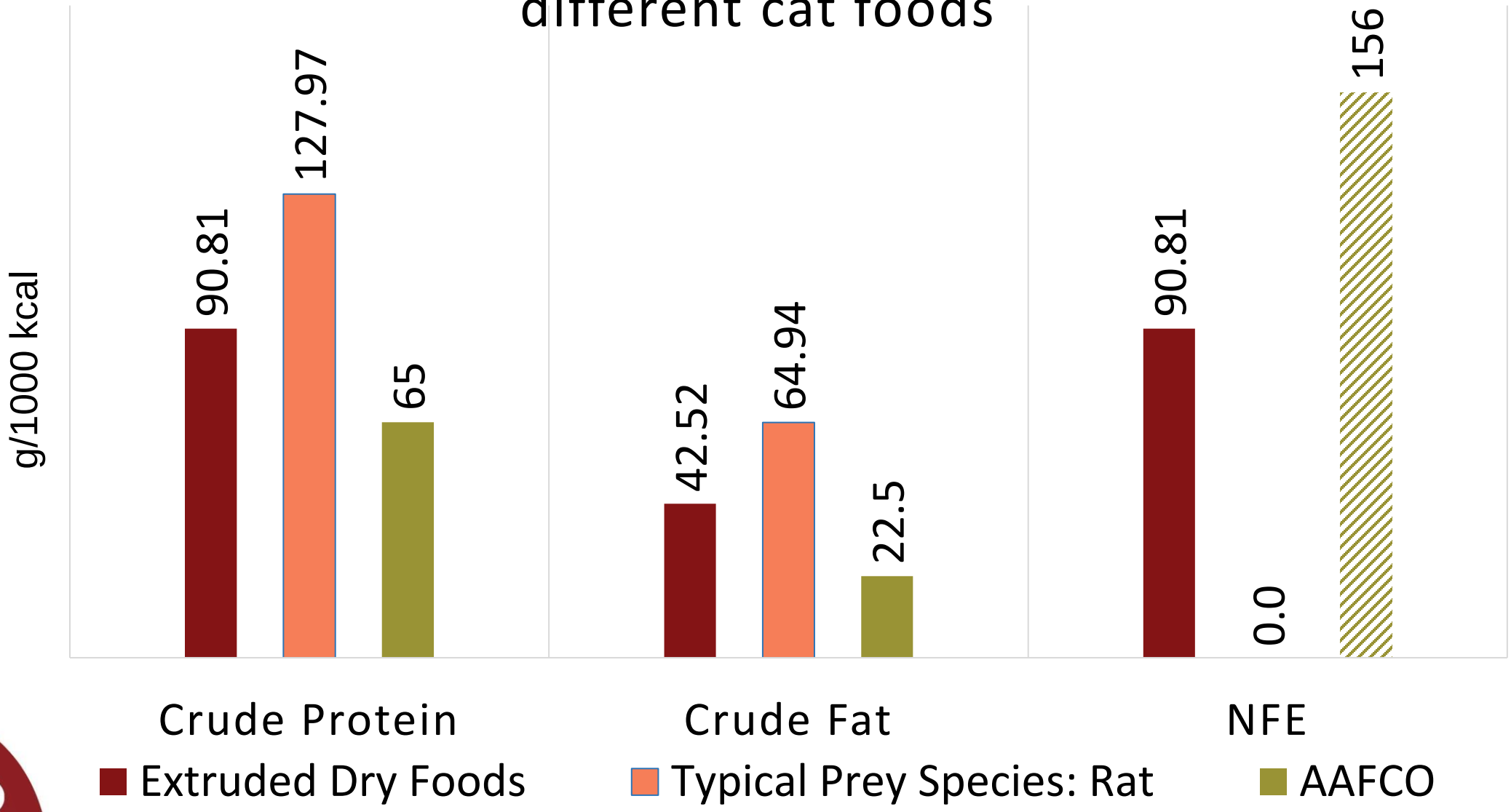
VS

Platinga et al., 2011; Davies et al., 2017; AAFCO, 2021

# Comparison of macronutrient compositions in different cat foods



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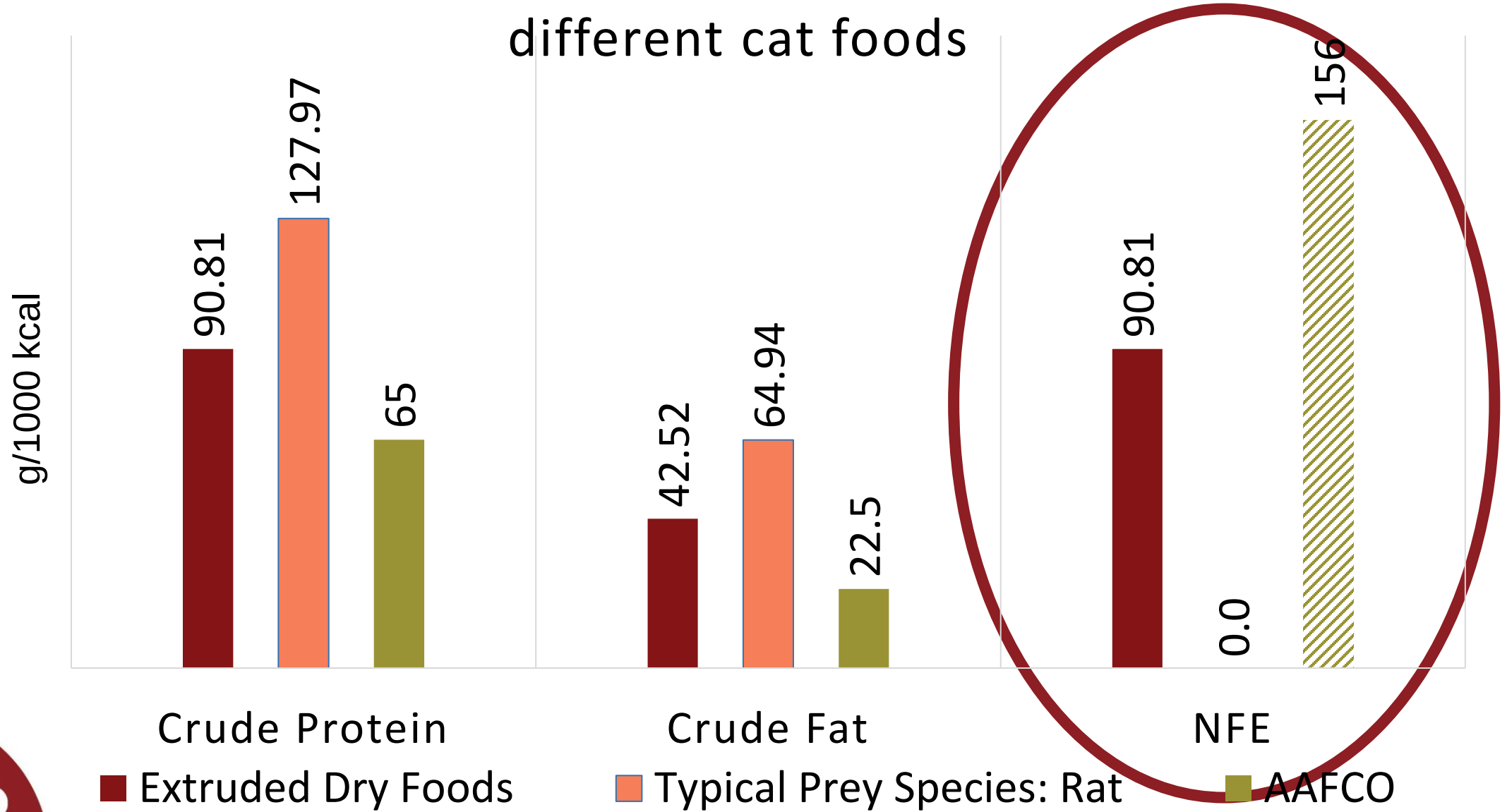
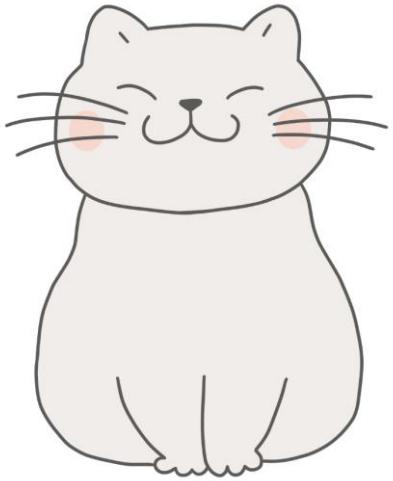


Morris et al., 1977; Kienzle, 1993c; de-Oliveira et al., 2008; Verbrugghe and Hesta, 2017

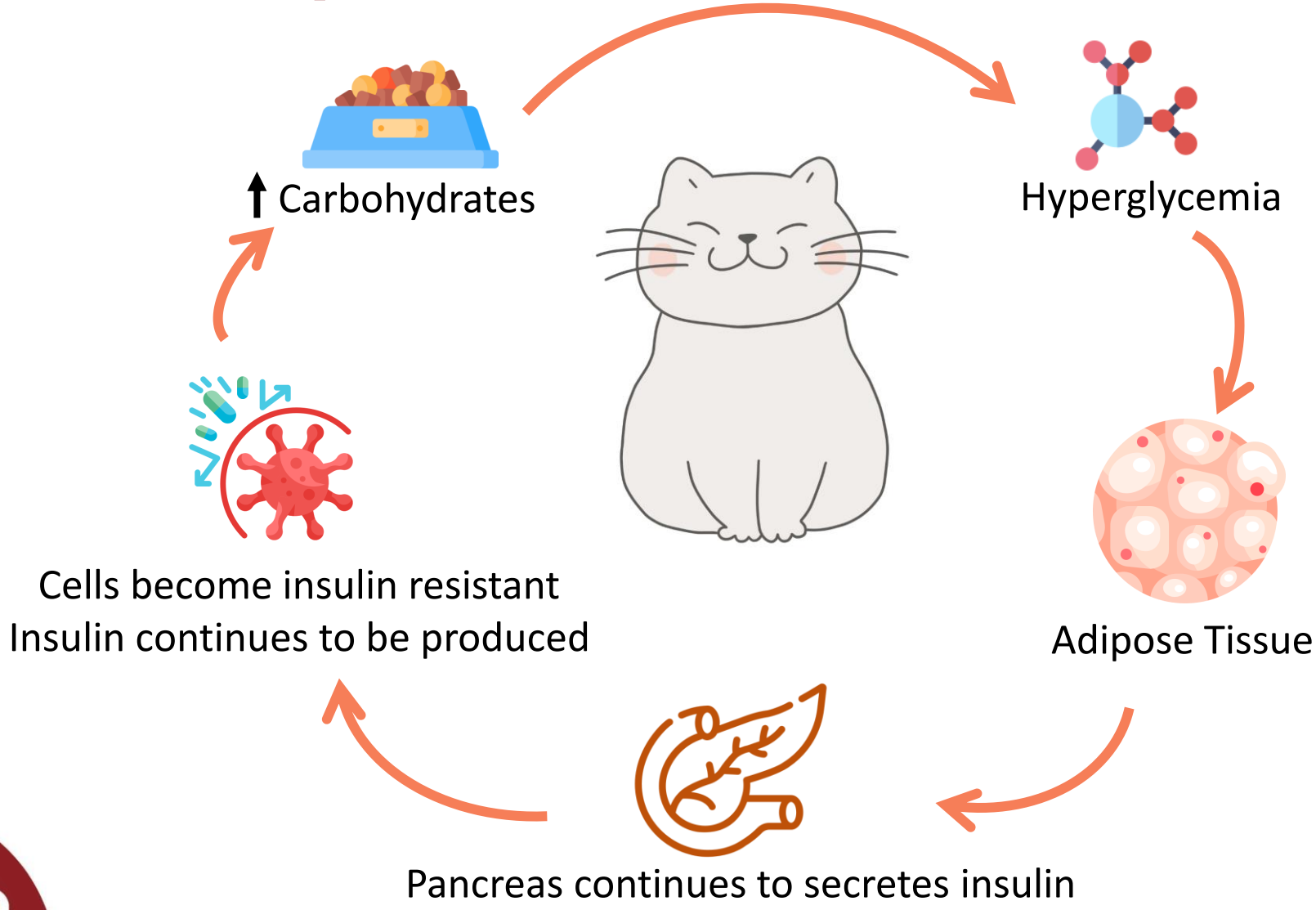
# NFE – Obesity – Insulin Resistance



**Reduced capacity to digest, absorb, and metabolize carbohydrates**

Buffington, 2008; Villaverde and Fascetti, 2014; Rowe et al., 2015

# NFE – Obesity – Insulin Resistance



Hoenig et al., 2007; Verbrugghe et al., 2010; Coradini et al., 2011; Farrow et al., 2013

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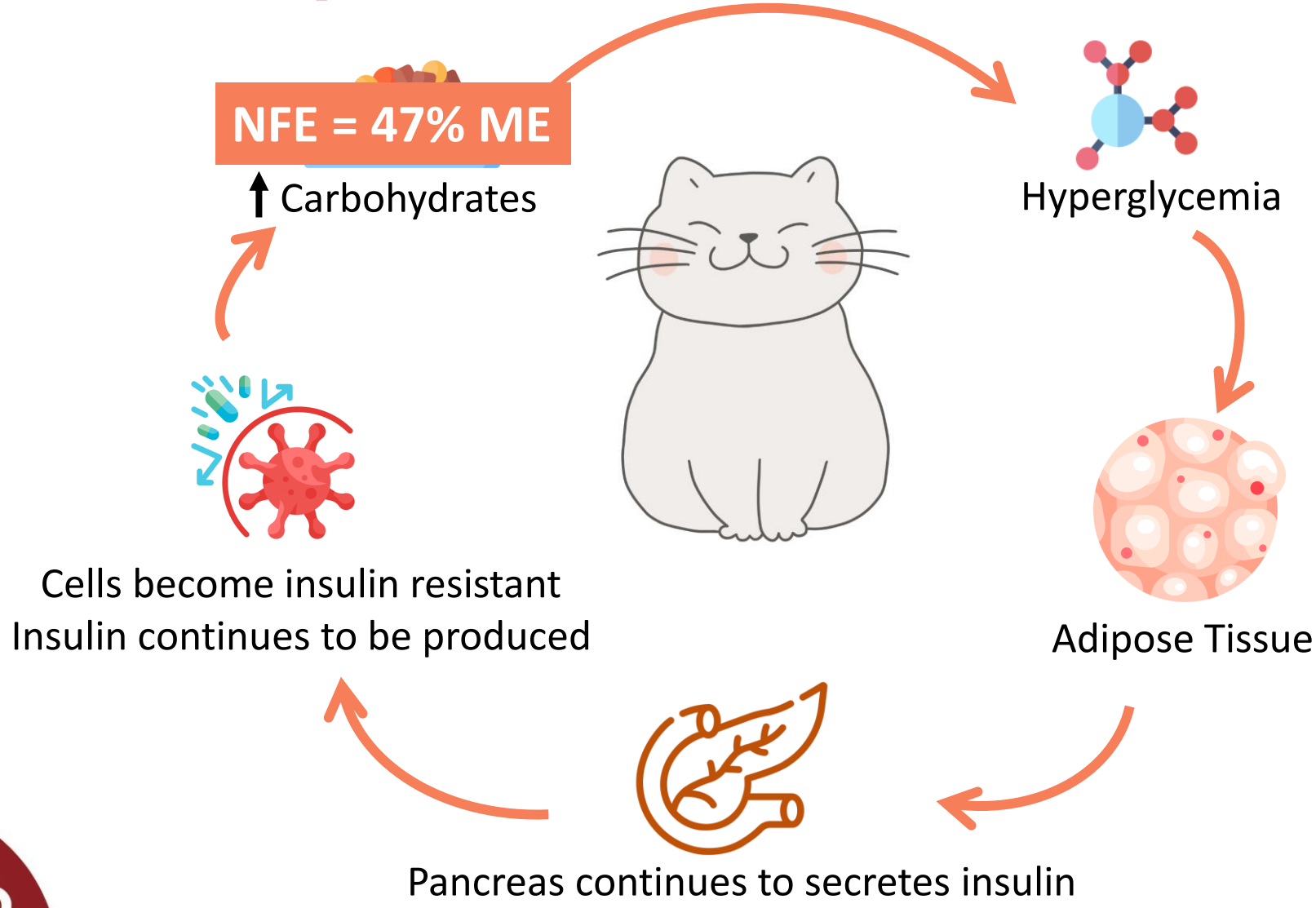

Gooding et al., 2014; Gooding et al., 2015; Nguyen et al., 2004; Backus et al., 2007

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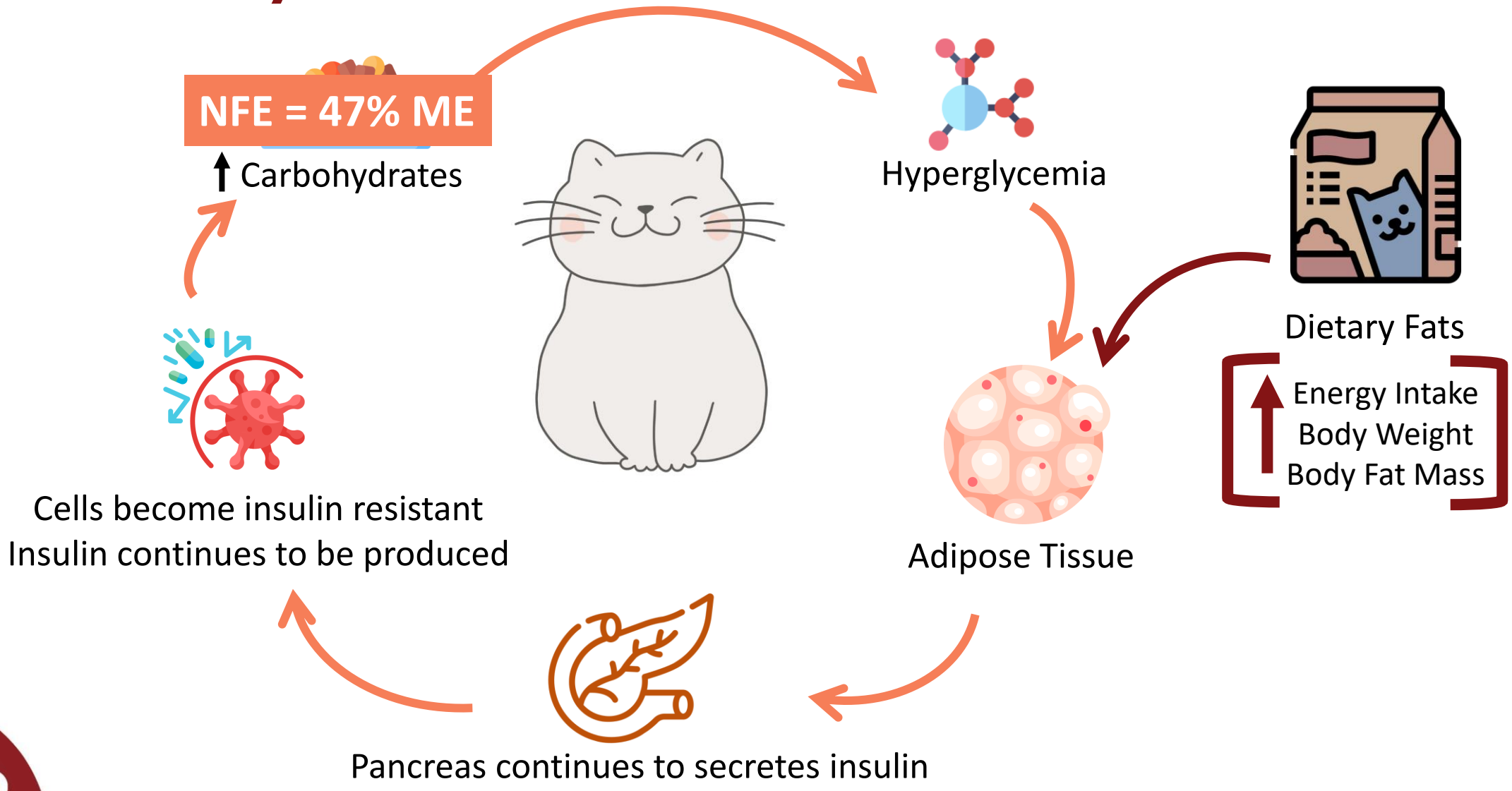

JOURNAL ARTICLE ACCEPTED MANUSCRIPT

# A meta-analysis: Dietary carbohydrates do not increase body fat or fasted insulin and glucose in cats

Hannah Godfrey, Jennifer L Ellis, Adronie Verbrugghe

*Journal of Animal Science*, skaf071, https://doi.org/10.1093/jas/skaf071

**Published:** 07 March 2025 **Article history** ▾

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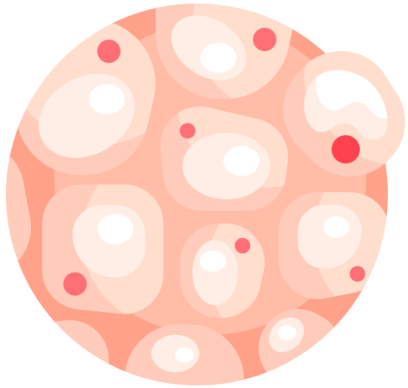
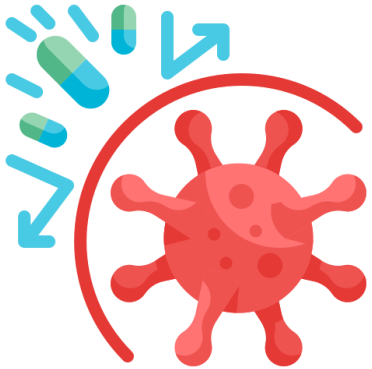


Body Fat Mass (BFM, kg)



Fasted Insulin (pmol/L)

Fasted Glucose (mmol/L)

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1

Database Search

2

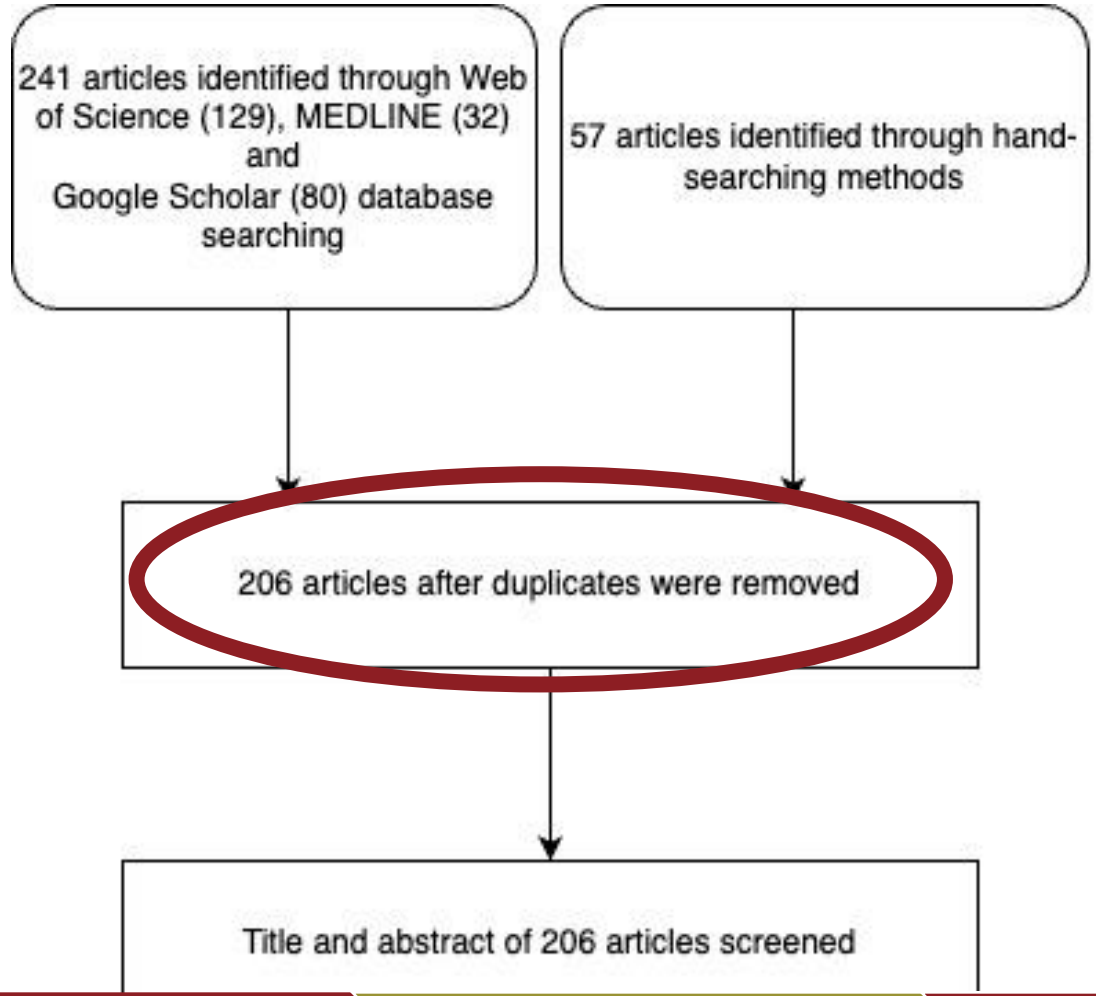
Screening/Eligibility

3

Database & Model Building

1

# Database Search



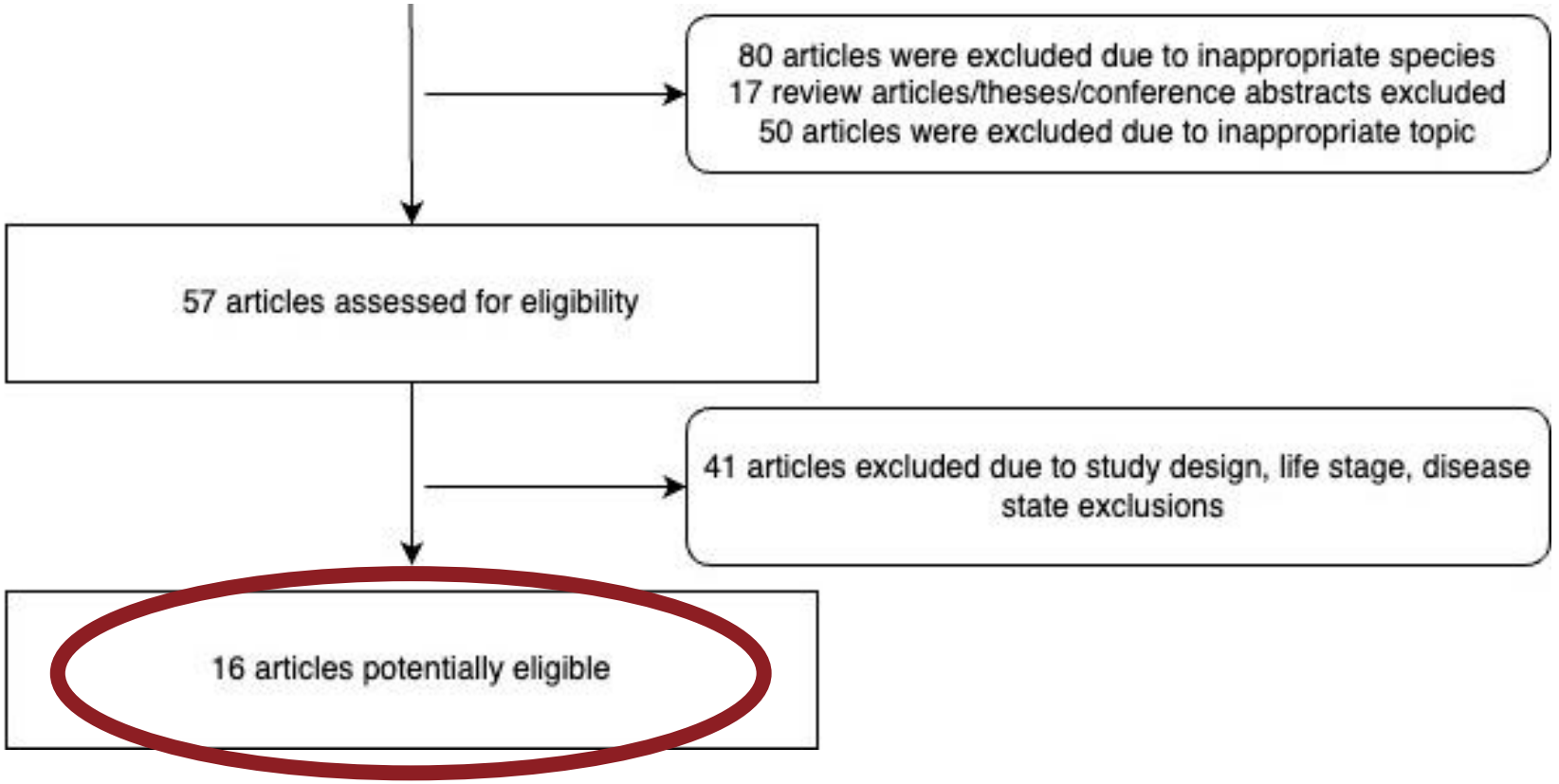
2

# Screening/Eligibility

| Inclusion | Exclusion |
| --- | --- |
| Primary research articles | Conference abstracts, review articles, book chapters, academic theses |
| “Cat” or “feline” was required to be included in the title, abstract, or keywords. | Any health conditions (except for obese condition) |
| Minimum of two test diets (differing in NFE content) | Growth (< 6 months of age), pregnancy, and lactation |

2

# Screening/Eligibility



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3

# Database & Model Building

**Driving variables used in models for BFM, fasted insulin, and fasted glucose**

| Continuous | Categorical |
|---|---|
| NFE (% ME) | Study design |
| Fat (% ME) | Feeding Method |
| Protein (% ME) | Body Condition* |
| DEI (kcal/kg BW) | NFE Level (high, moderate, low)* |
| BW (kg)* | Fat Level (high, moderate, low)* |
| BFM (kg)* | Protein Level (high, moderate, low)* |
| BF% (%)* | Trade |
| Study Length (weeks) | |

*Only used for fasted insulin and glucose models

3

# Database & Model Building

**Driving variables used in models for BFM, fasted insulin, and fasted glucose**

PROC MIXED procedure was used to assess mixed models within SAS Studio.

Univariate models:

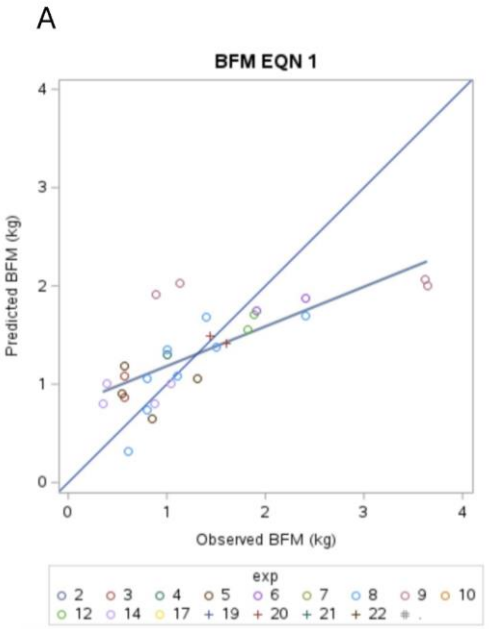
- NFE (% ME), Trade, or NFE Level was used
- Followed by addition of driving variables to build **multivariate models**

Cook's distance was utilized for detection of outliers

Study as random effect

# Results: Body Fat Mass (kg)

**A total of 25 multivariate models were built to predict BFM**




| Equation ID[1] | X Variables[2] | Parameter | Estimate | P-value[4] |
|---|---|---|---|---|
| **EQN-BFM1** | NFE, % ME | Intercept: | 2.214 (± 0.45) | 0.0012 |
| | DEI, kcal/kg BW | NFE (% ME)* DEI (kcal/kg BW): | – 0.00016 (± 0.00007) | 0.0396 |

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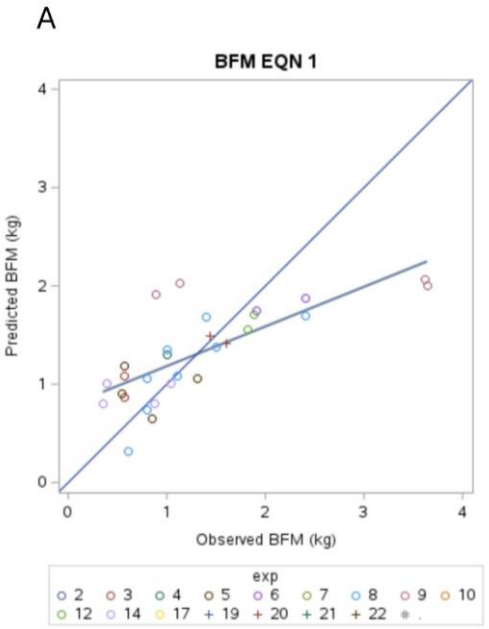


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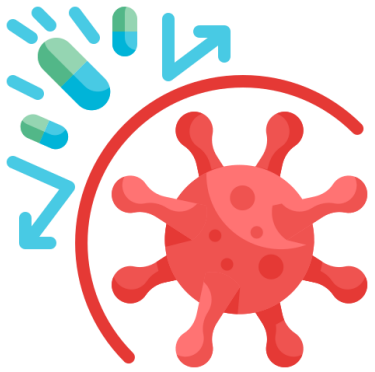
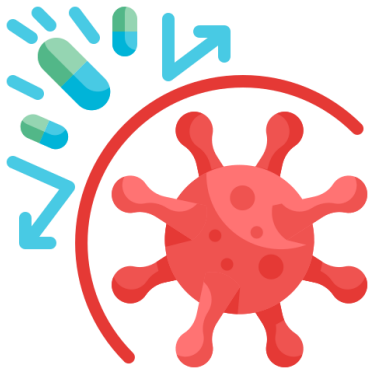
| | DEI, kcal/kg BW | **NFE (% ME)* DEI (kcal/kg BW):** | **– 0.00016 (± 0.00007)** | 0.0396 |



# Results: Fasted Insulin (pmol/L)

**A total of 153 multivariate models were built to predict fasted insulin**

| Equation ID | X Variables | Parameter | Estimate | P-value |
|---|---|---|---|---|
| **EQN-INS1** | NFE, % ME<br>BFM, kg | Intercept: | 53.143 (± 9.77) | 0.0028 |
| | | NFE (% ME)*BFM: | – 0.290 (± 0.15) | 0.0816 |
| **EQN-INS5** | NFE, % ME<br>DEI, kcal/kg BW<br>BW, kg | Intercept: | 51.639 (± 5.78) | <0.0001 |
| | | NFE (% ME)*DEI (kcal/kg BW)*BW (kg): | – 0.00012 (± 0.0003) | 0.6882 |



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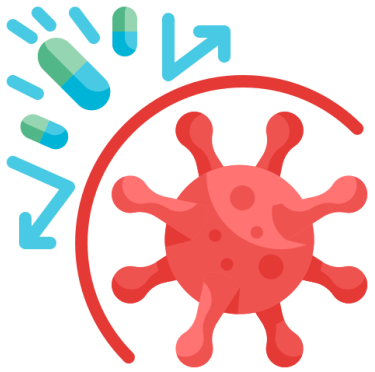

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# Results: Fasted Glucose (mmol/L)

**A total of 153 multivariate models were built to predict fasted glucose**

| Equation ID | X Variables | Parameter | Estimate | P-value |
|---|---|---|---|---|
| **EQN-GLUC2** | NFE, % ME<br>BF% | Intercept: | 4.213 (± 0.40) | <0.0001 |
| | | NFE (% ME): | 0.0023 (± 0.004) | 0.5320 |
| | | BF%: | 0.017 (± 0.01) | 0.1237 |
| **EQN-GLUC6** | NFE Level<br>DEI, kcal/kg BW<br>BW, kg | Intercept: | 4.436 (± 0.45) | <0.0001 |
| | | NFE Level: High | 0.339 (± 0.12) | 0.0292 |
| | | NFE Level: Moderate | 0 | |
| | | NFE Level: Low | 0.242 (± 0.12) | |
| | | DEI (kcal/kg BW): | – 0.0054 (±0.003) | 0.1039 |
| | | BW (kg): | 0.074 (± 0.08) | 0.3695 |

# Results: Fasted Glucose (mmol/L)

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| | | **NFE (% ME):** | **0.0023 (± 0.004)** | **0.5320** |
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# Conclusions of Meta-Analysis

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## Carbohydrate-Obesity Myth?

Carbohydrates (NFE) do not appear to be a risk factor for greater BFM

2

## Insulin Sensitivity?

Fasted concentrations of insulin and glucose were not affected by dietary NFE content

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## Fat Focus

Dietary fat content may pose a greater risk factor for feline obesity

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## Fat Focus

Dietary fat content may pose a greater risk factor for feline obesity

# Animal Trial

Mitacs

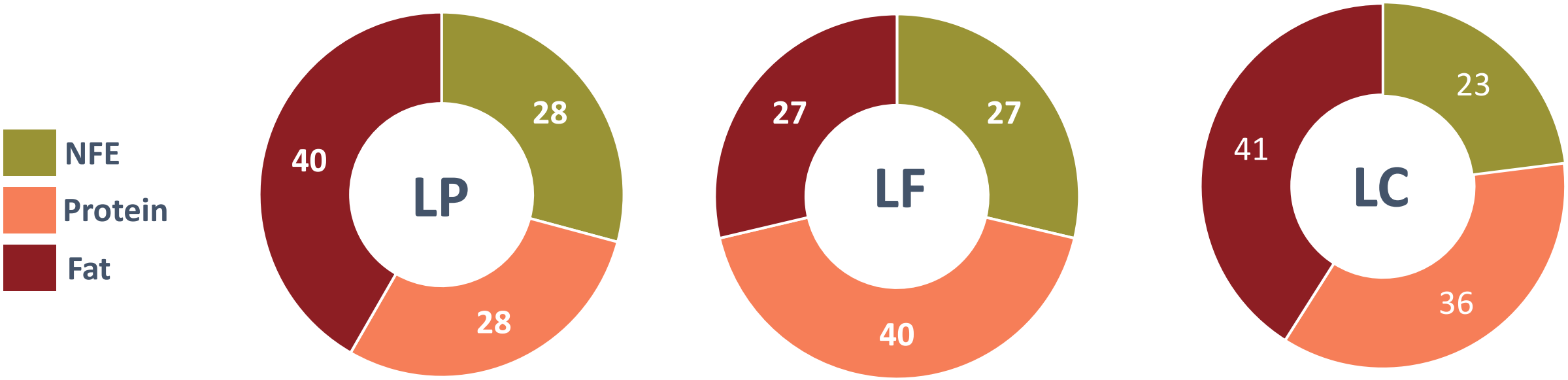
NSERC CRSNG

Champion Petfoods
World's Best Petfood

PETFOOD FORUM

# Animal Trial: Experimental Diets

**Macronutrient distribution (%ME) of test diets formulated via isoenergetic substitution**



# Animal Trial: Study Design

*3x3 Latin square design*

**Adult neutered male cats**

*n=18*

Obese (BCS = 8 or 9)

*n=9*

Lean (BCS = 4 or 5)

*n=9*

Maintain BW

University of Guelph

4-Weeks

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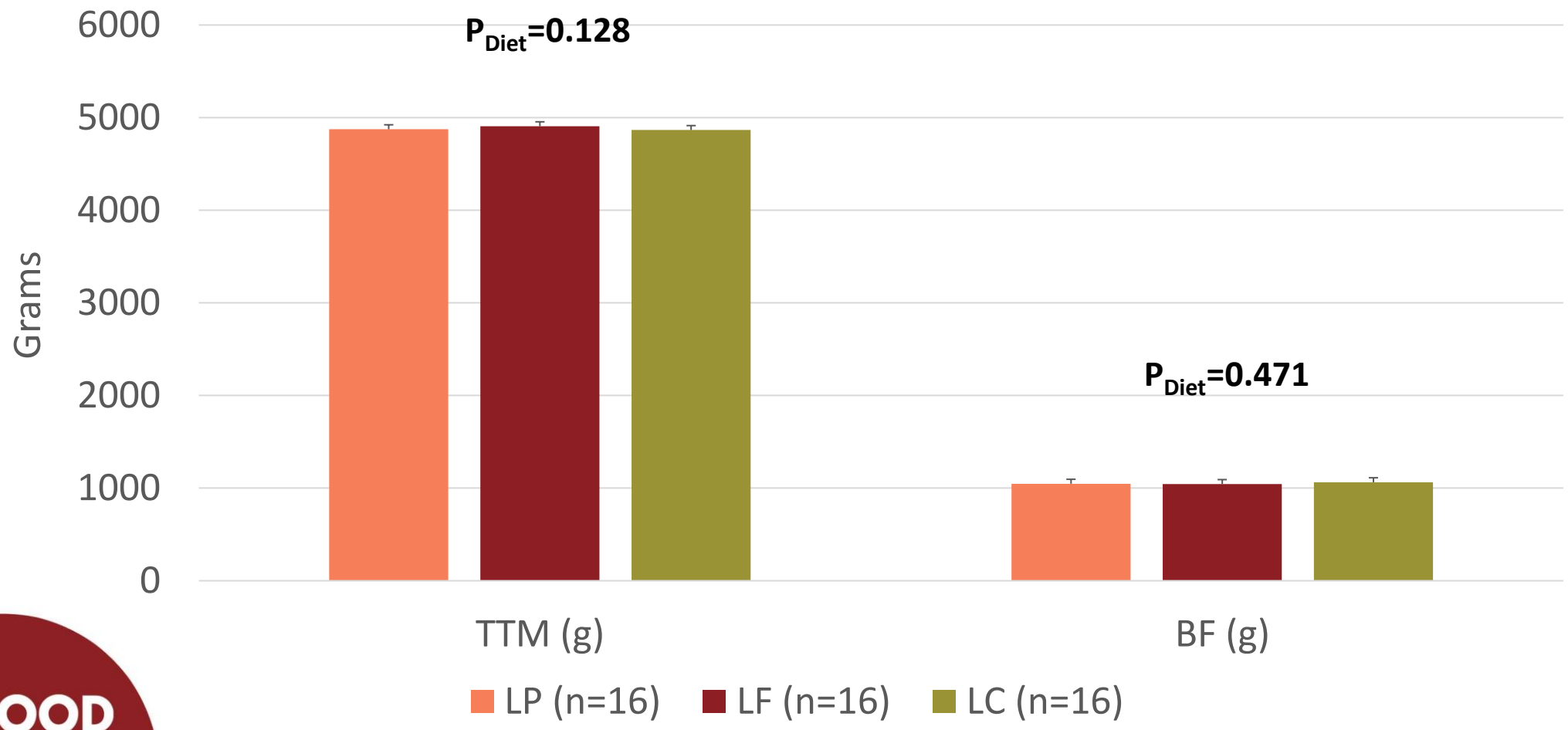
**Dual Energy X-Ray Absorptiometry Meal Test**

# Animal Trial: Results – Body Composition



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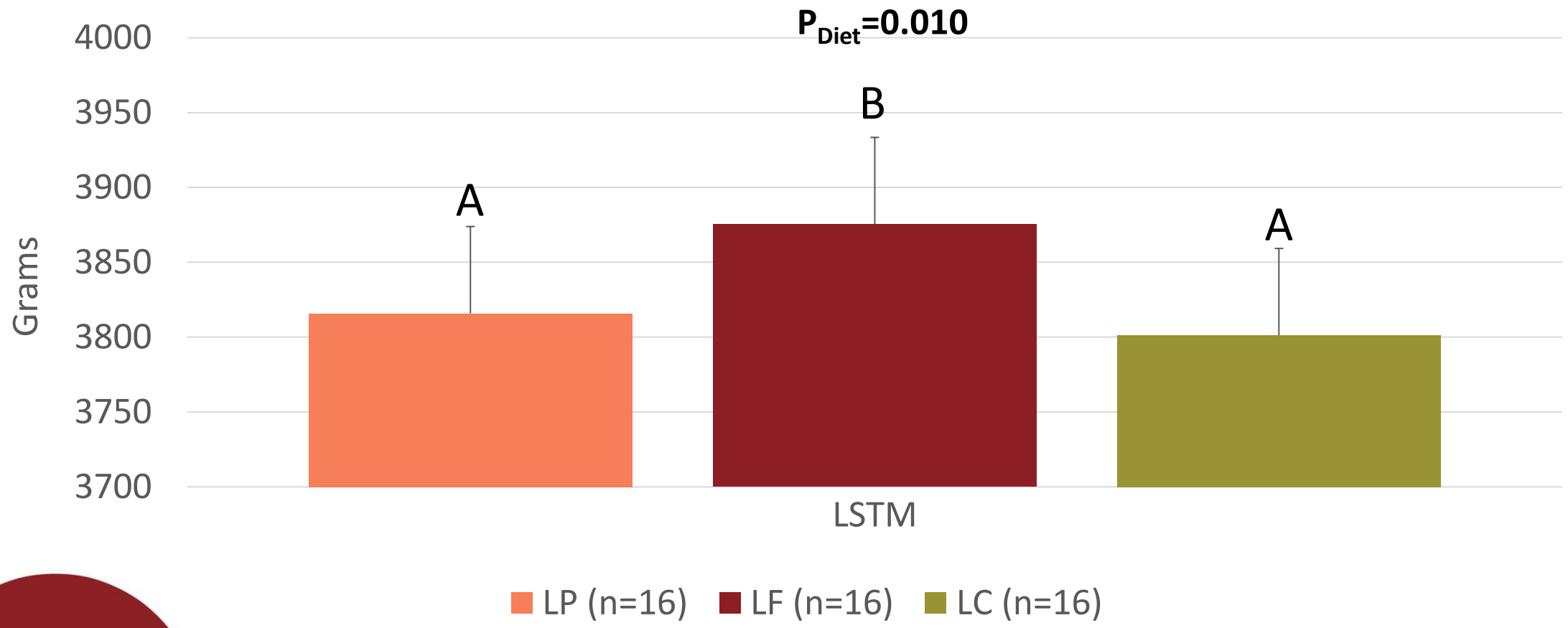


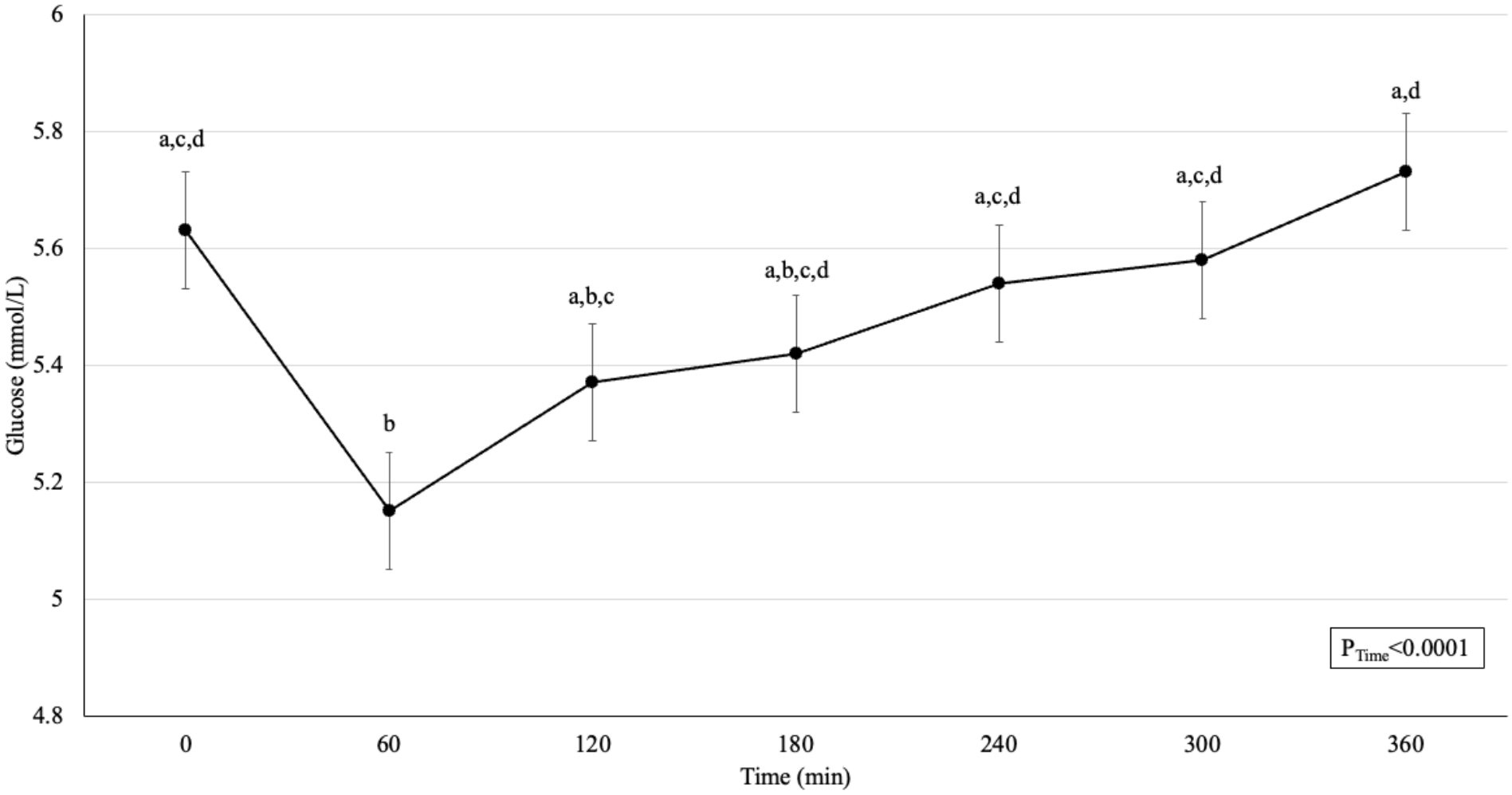
# Animal Trial: Results – Glucose (mmol/L)

## Fasted

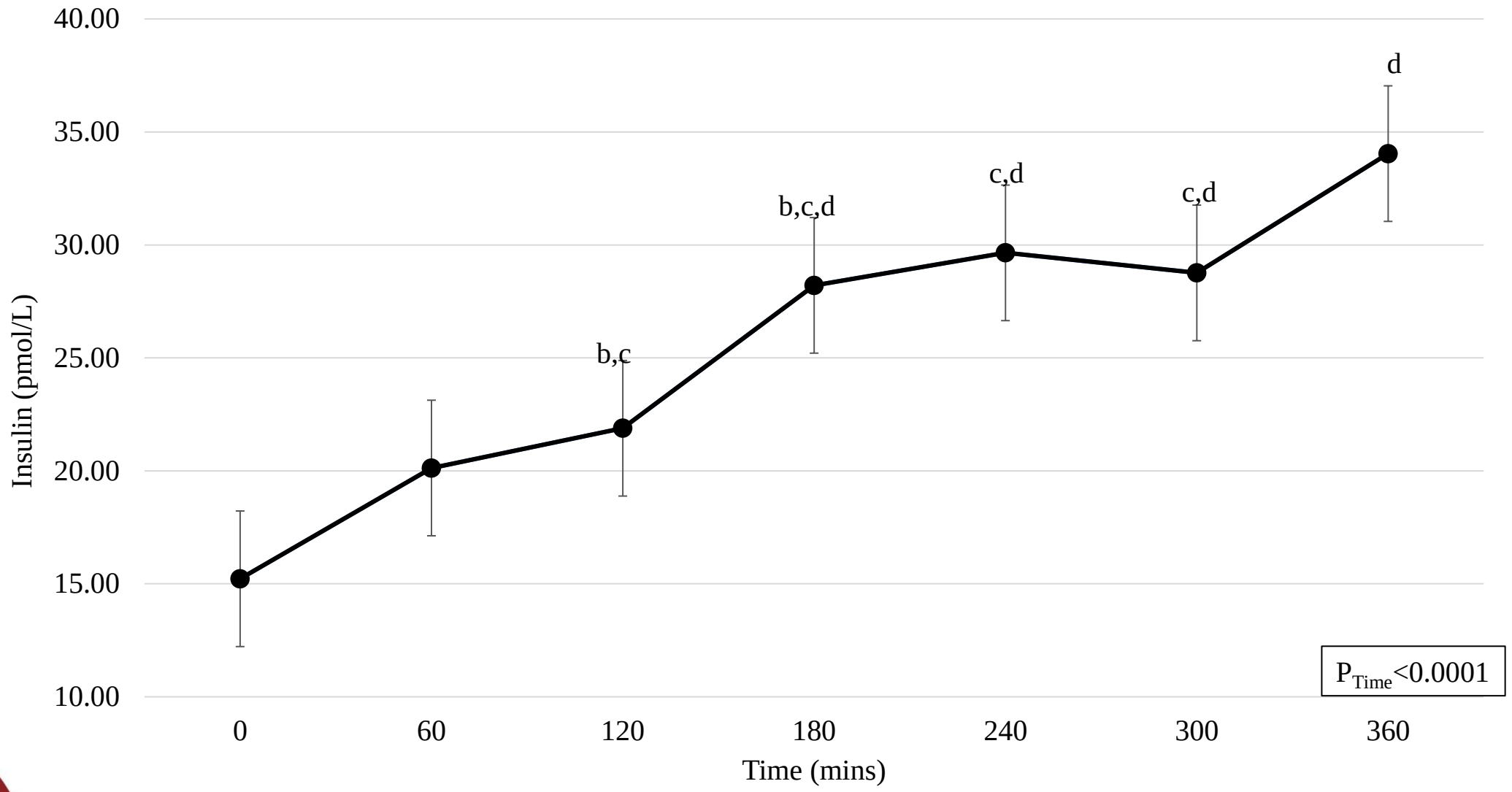
- $P_{BC}$=0.5004
- $P_{Diet}$=0.7452
- $P_{BC*Diet}$=0.7135

## Post-Prandial

- $P_{BC*Time}$=0.6682
- $P_{Diet*Time}$=0.9356
- $P_{BC*Diet*Time}$=0.1272



# Animal Trial: Results – Serum Insulin (pmol/L)



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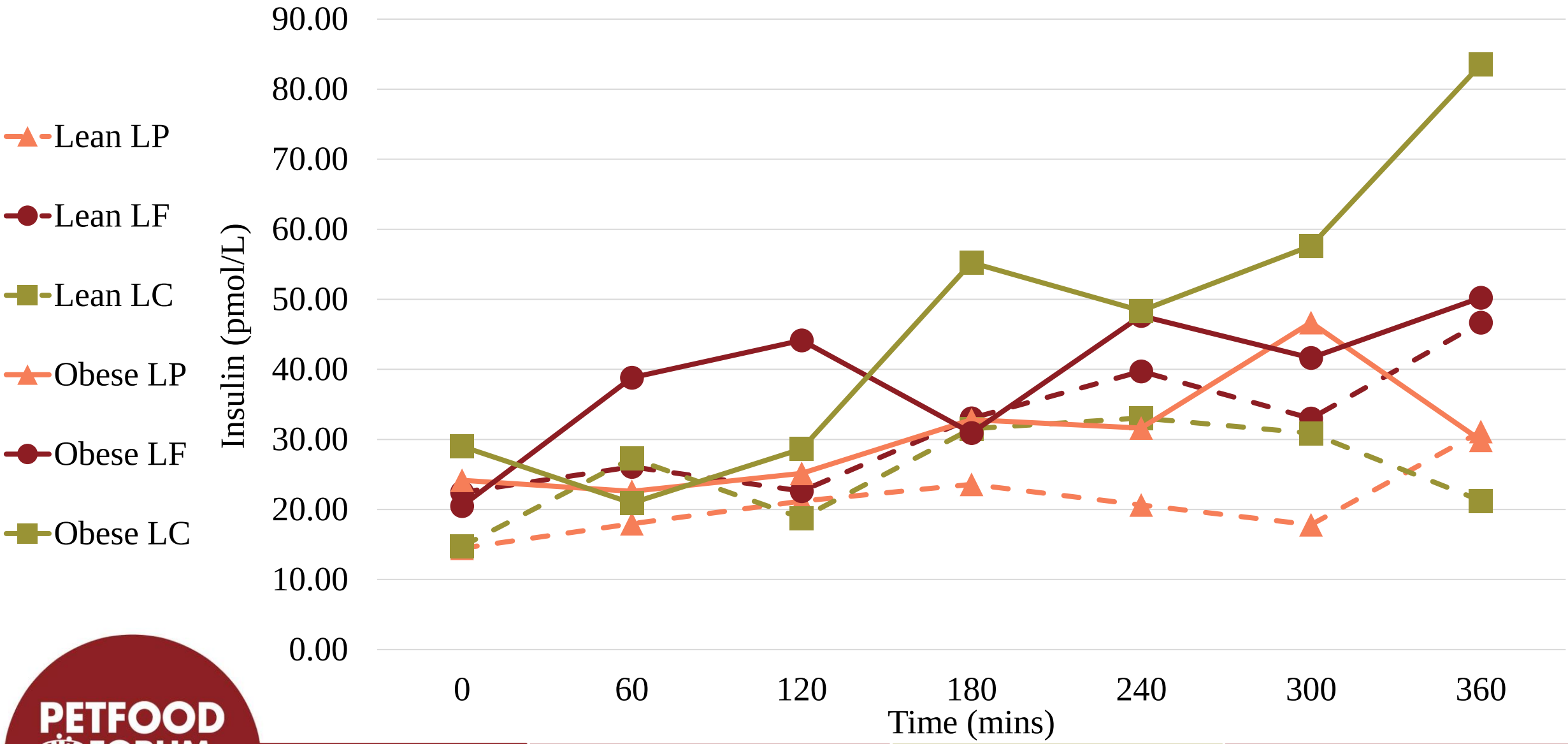

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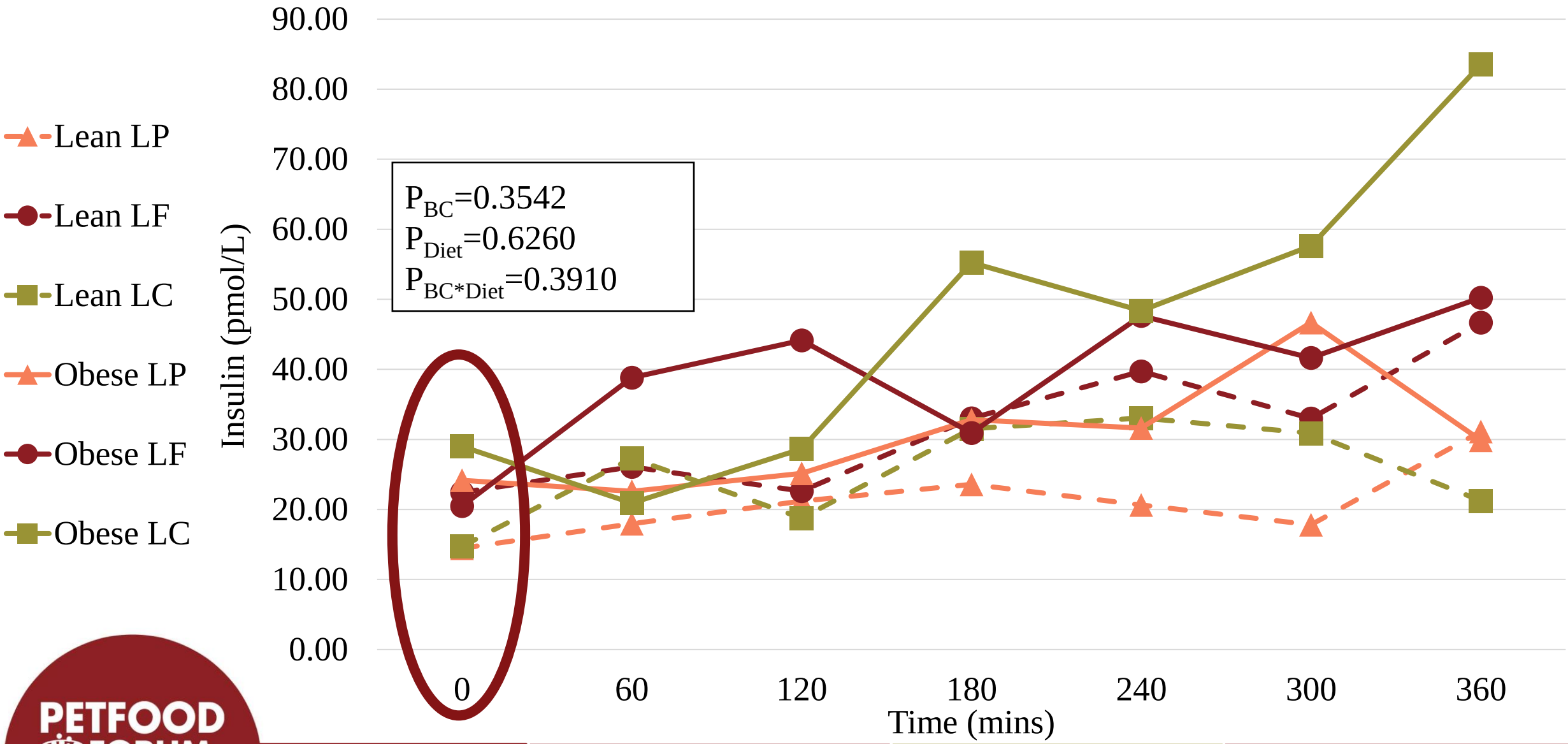

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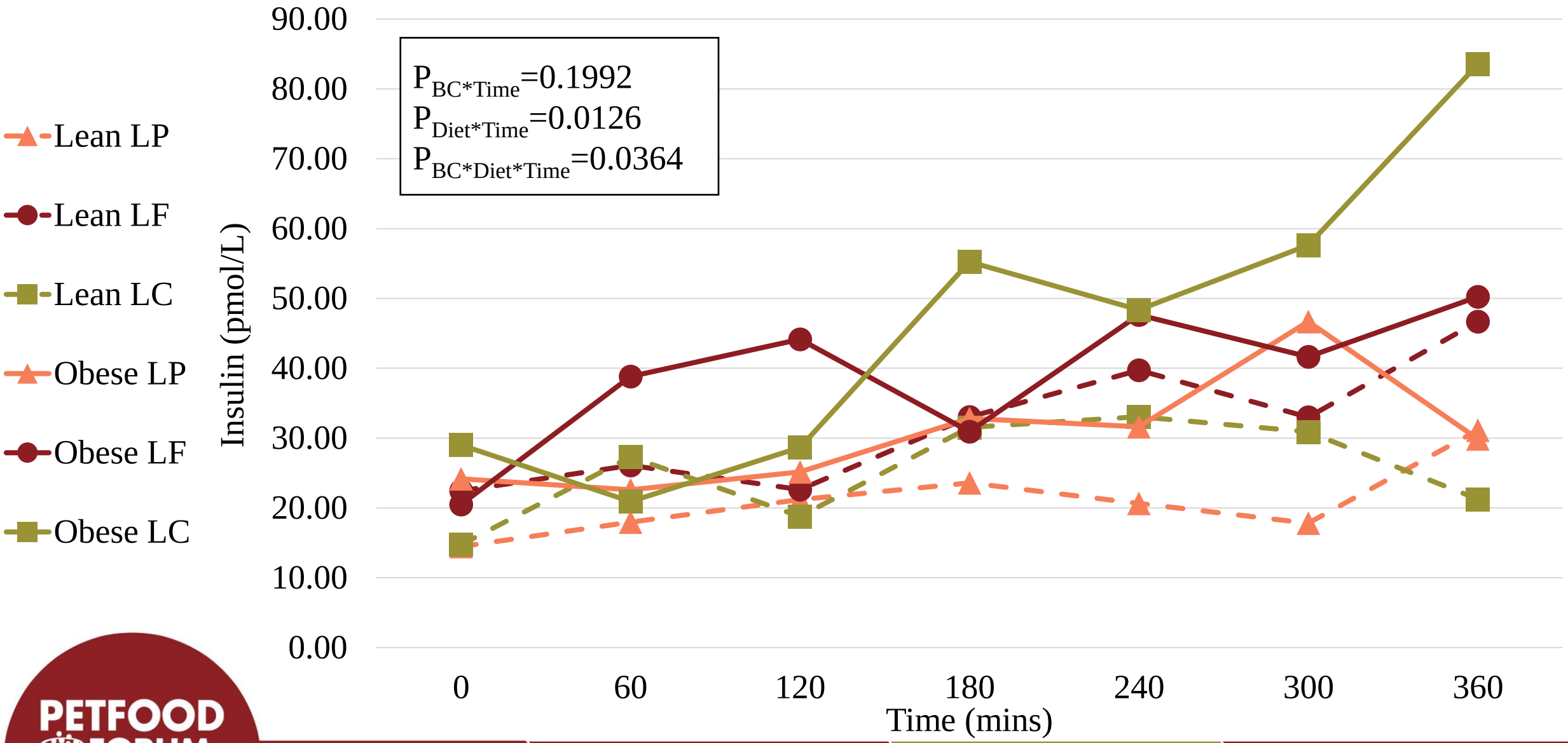

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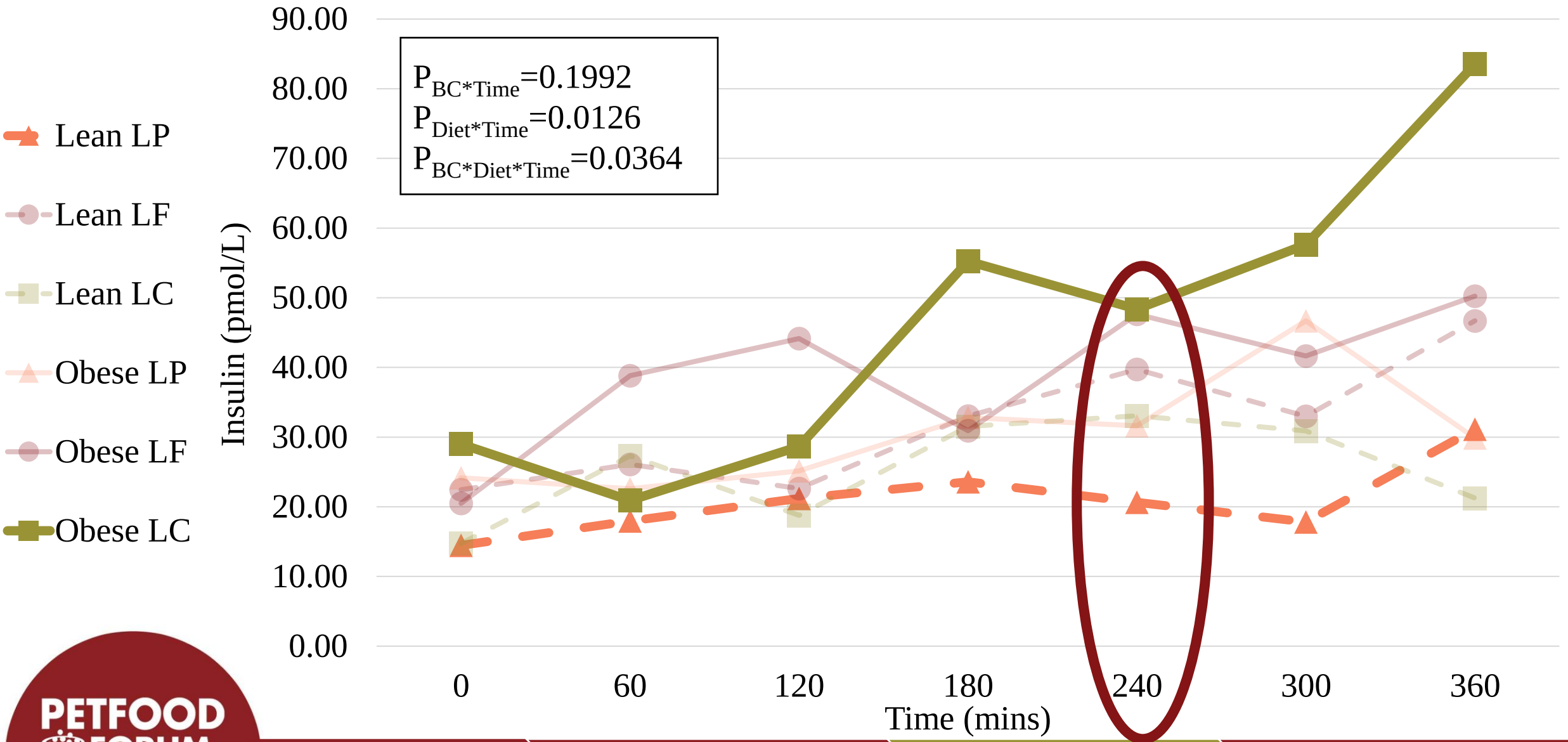

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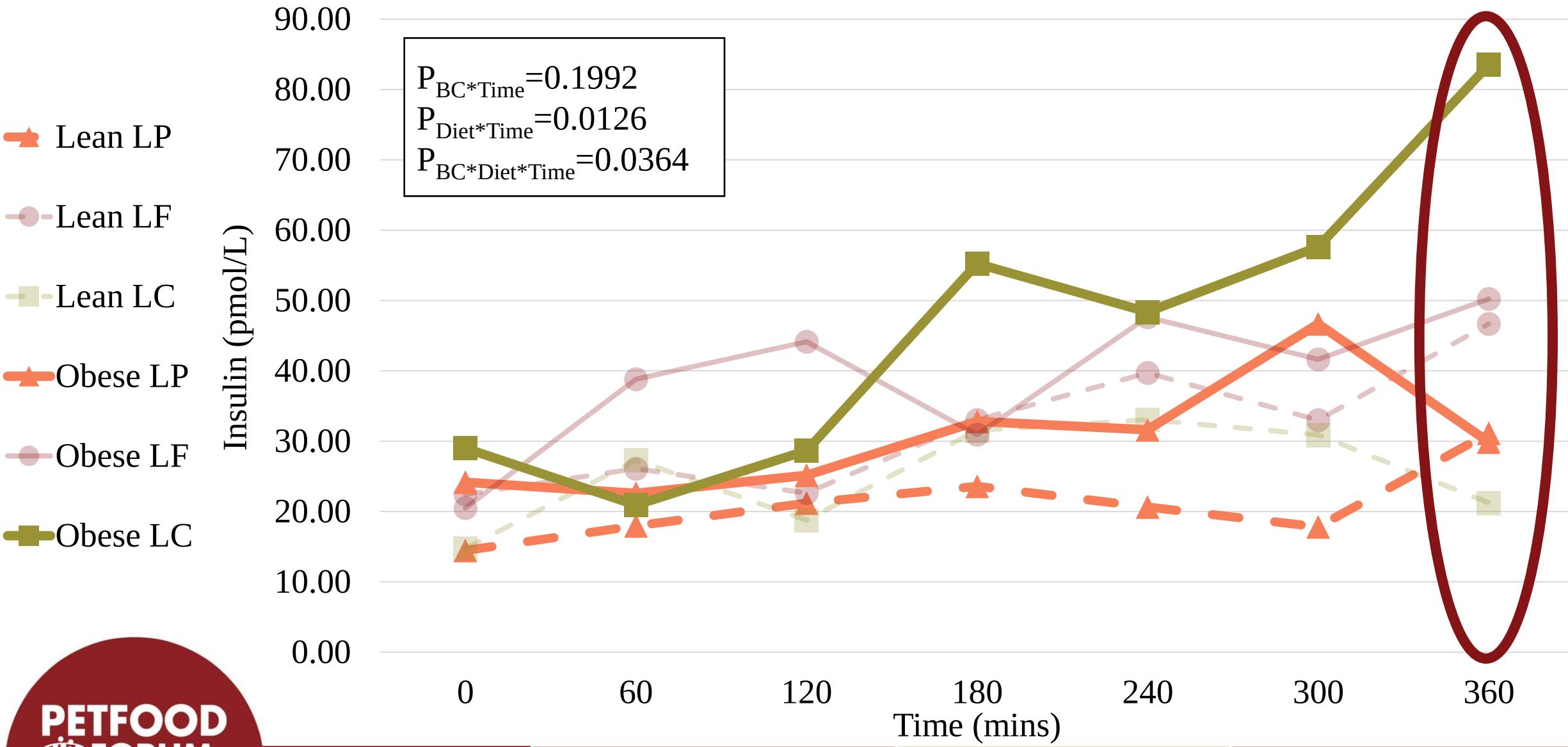

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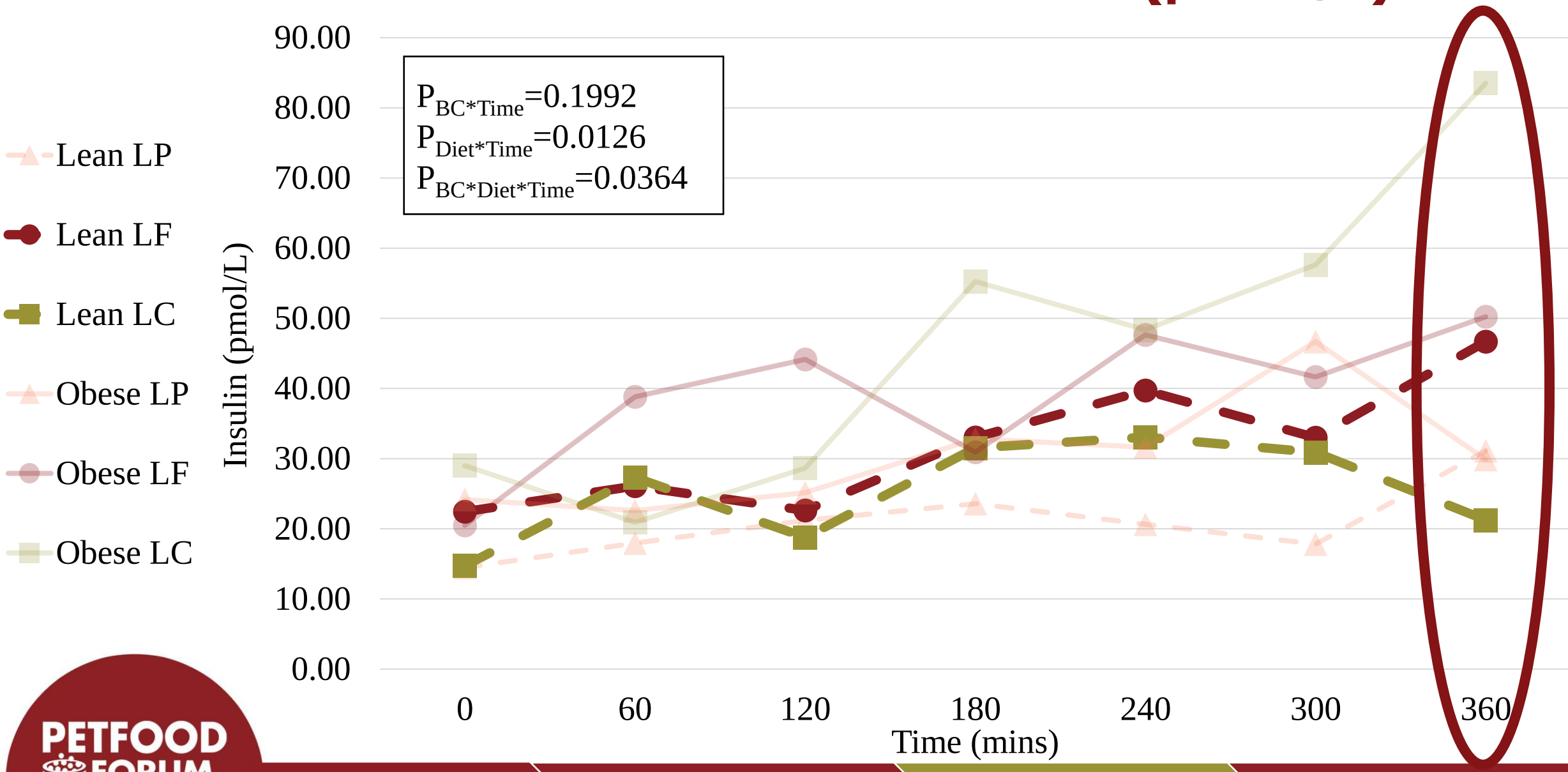

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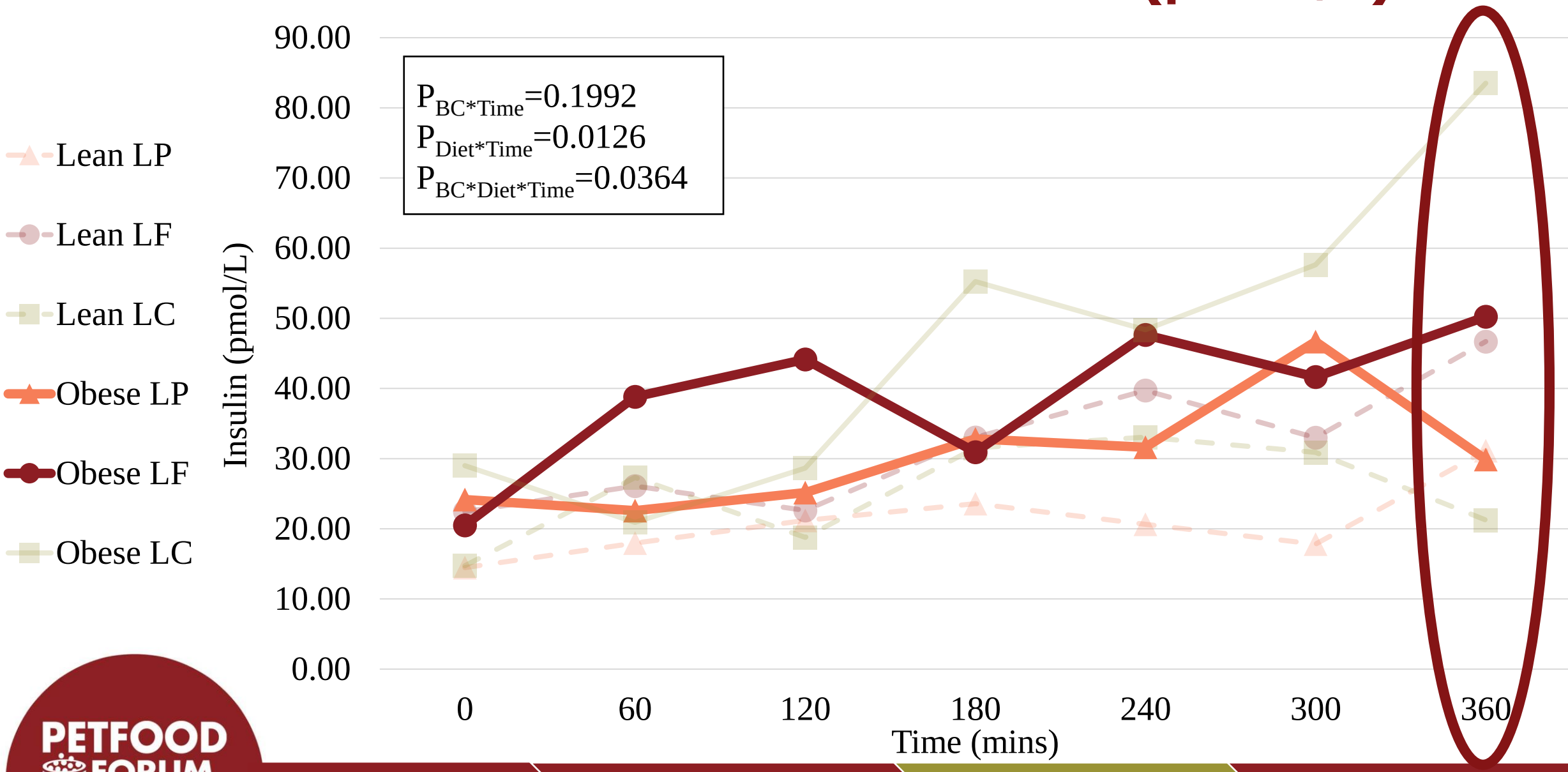

# Animal Trial: Results – Insulin/Glucose

| | LP | LF | LC | $P_{Diet}$ |
|---|---|---|---|---|
| $iAUC_{Glu}$, mmol/L × min | -19.42 ±41.49 | 4.88 ±42.84 | -53.71 ±41.47 | 0.6678 |
| $iAUC_{Ins}$, pmol/L × min | 3136.35 ± 982.19 | 4731.37 ± 940.10 | 4987.12 ± 909.43 | 0.3523 |
| $iAUC_{Ins}$:$iAUC_{Glu}$ | 18.18 ± 7.91 | 40.14 ± 15.58 | 92.56 ± 41.40 | 0.1701 |

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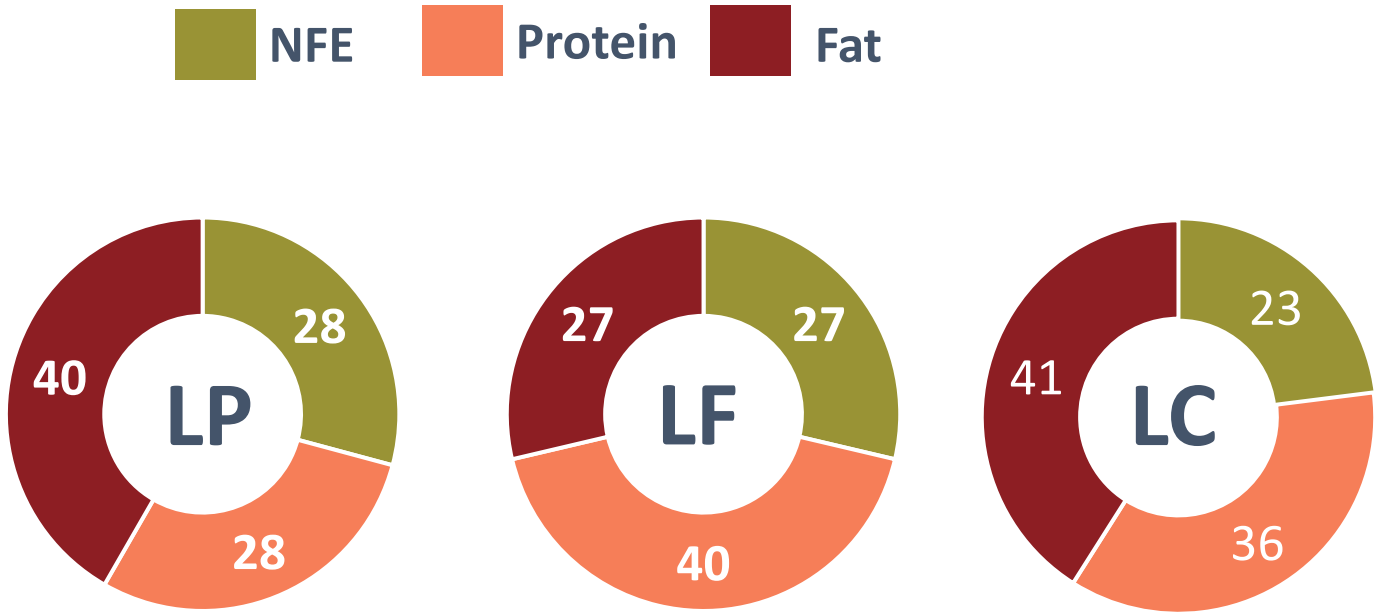


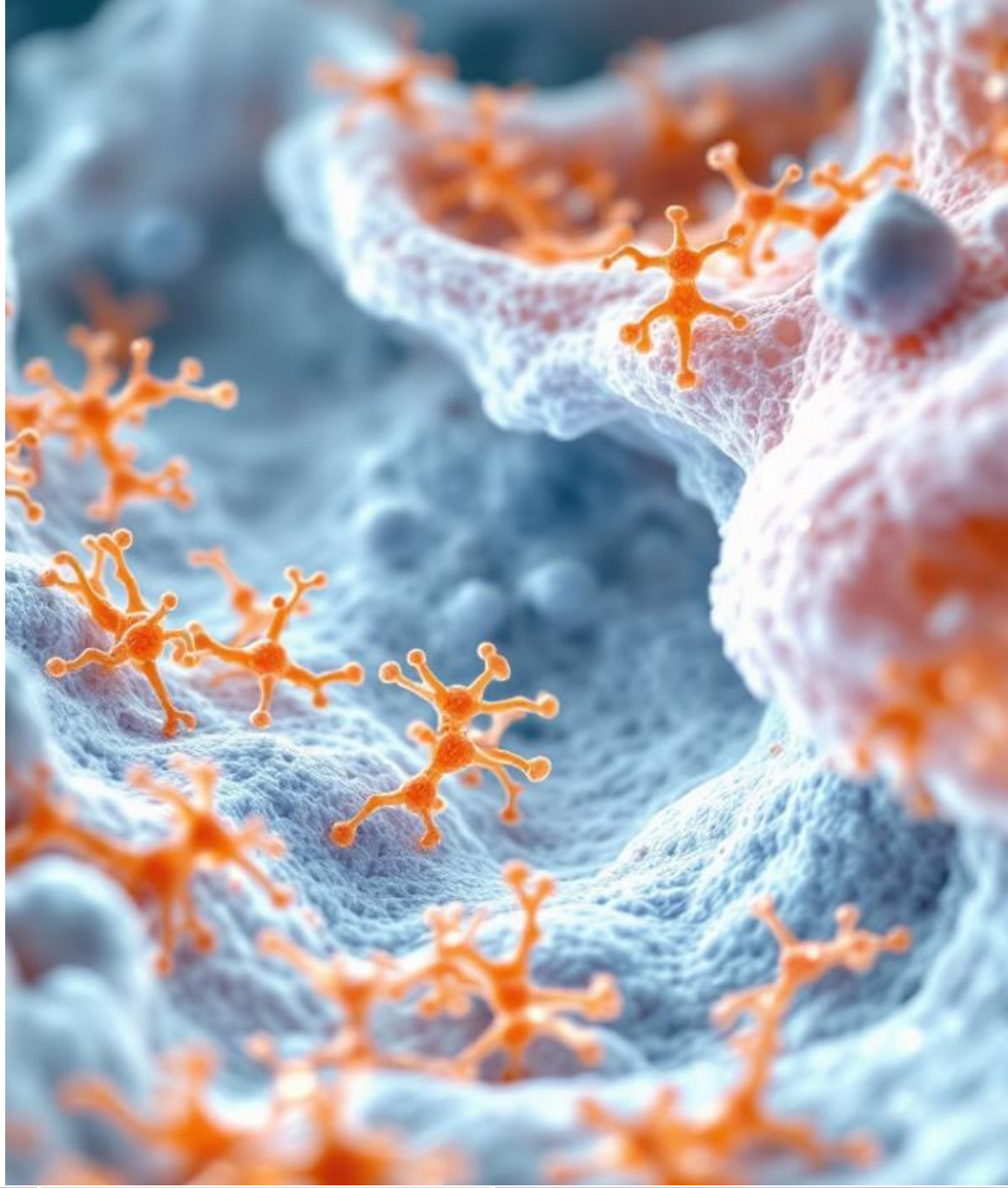

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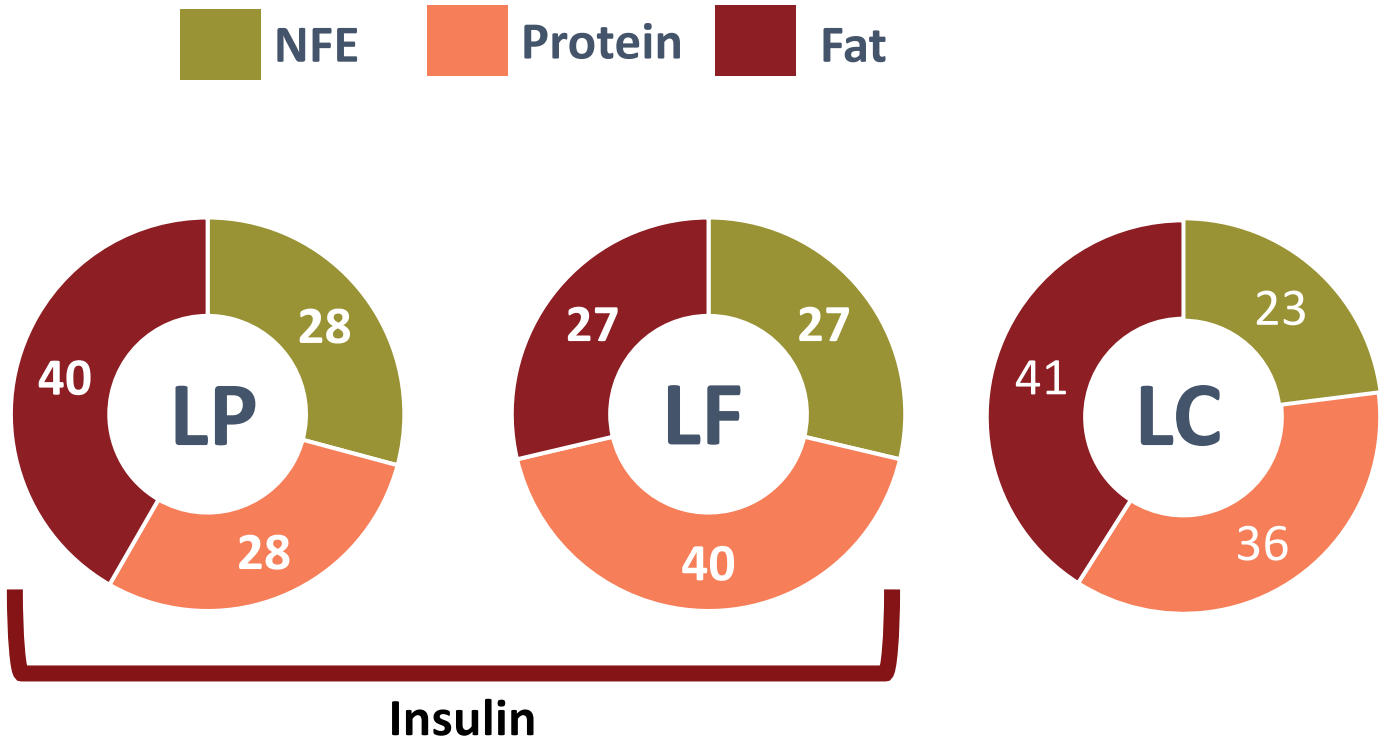
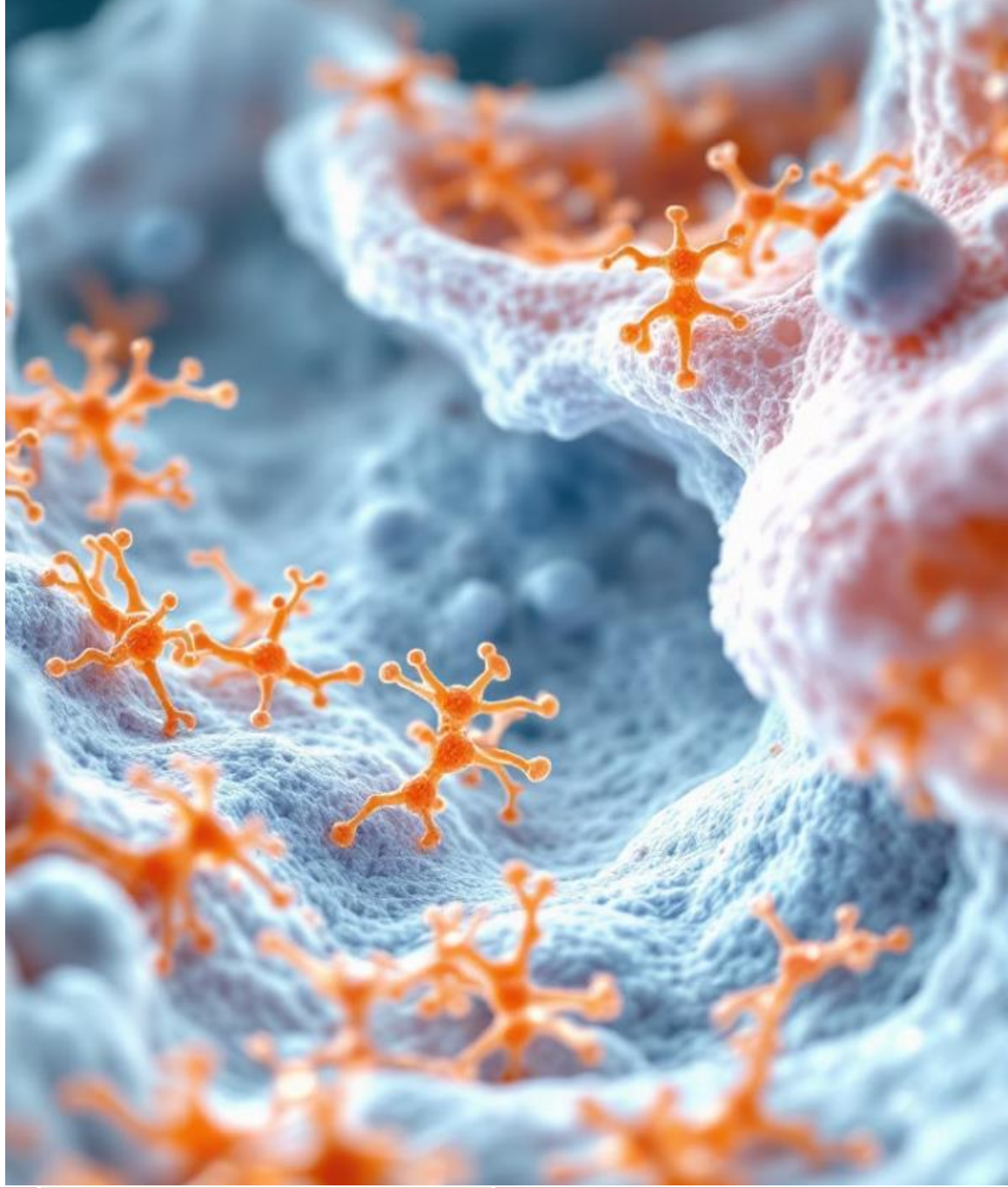
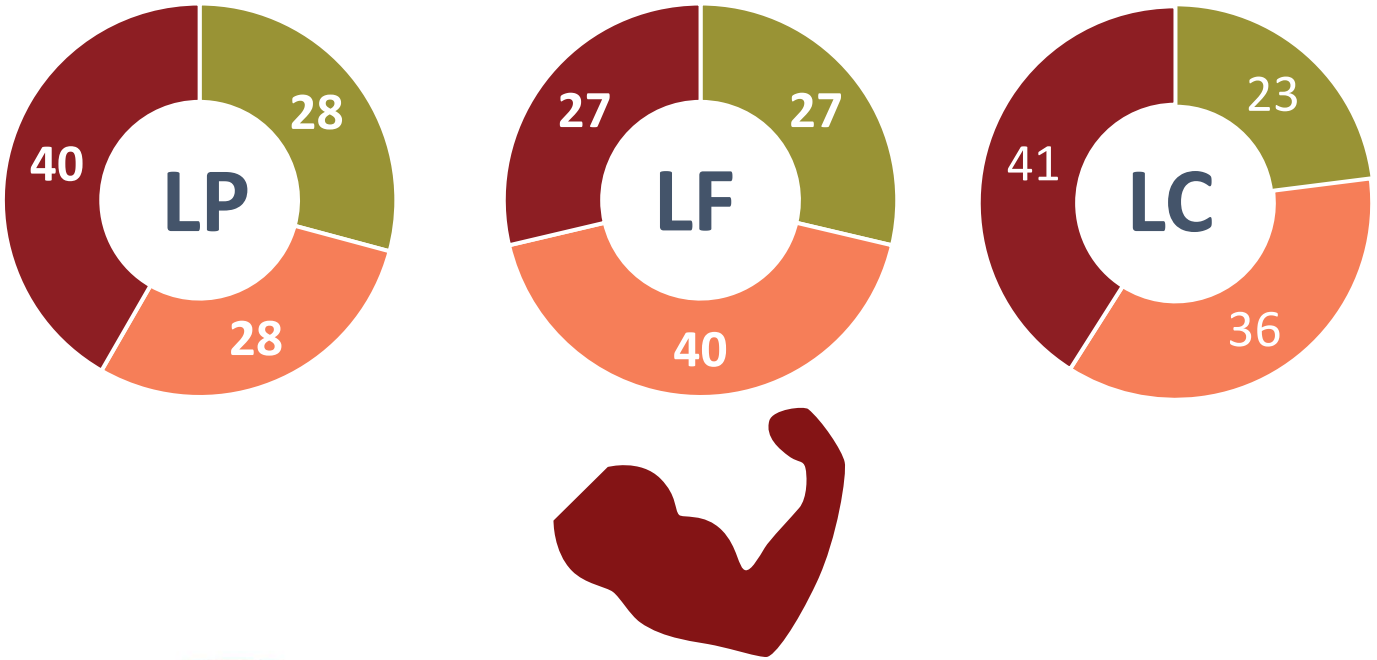
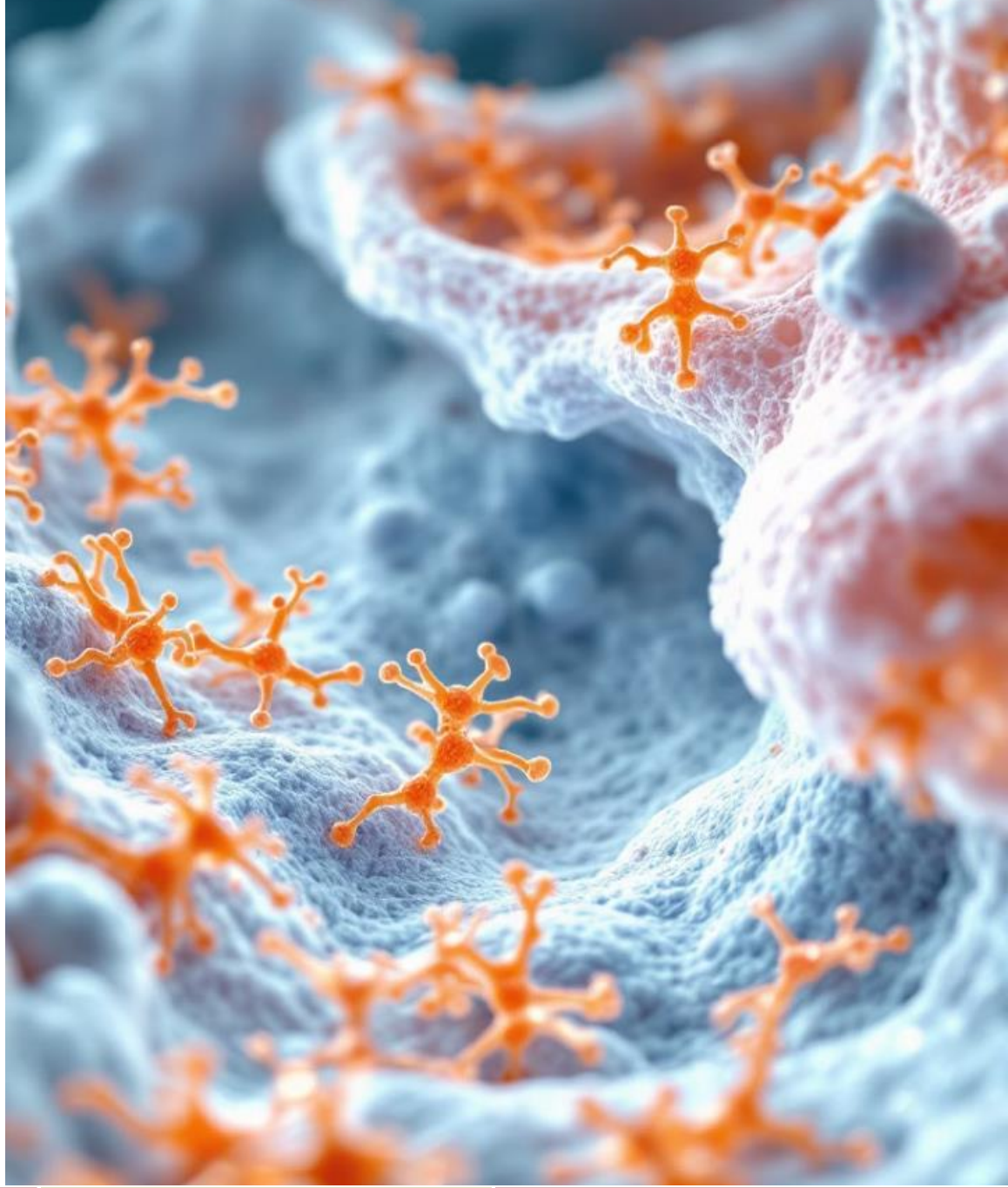


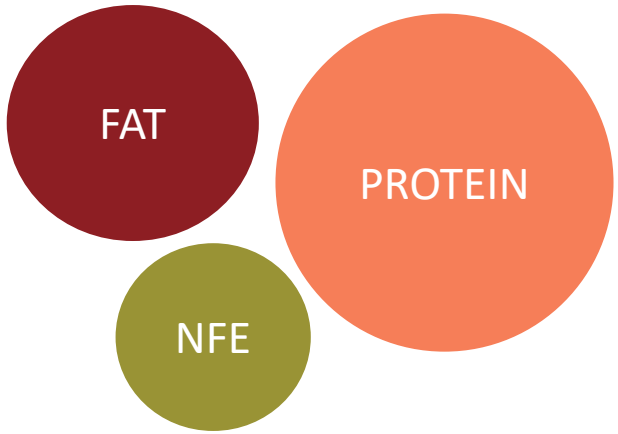
# Animal Trial: Conclusion

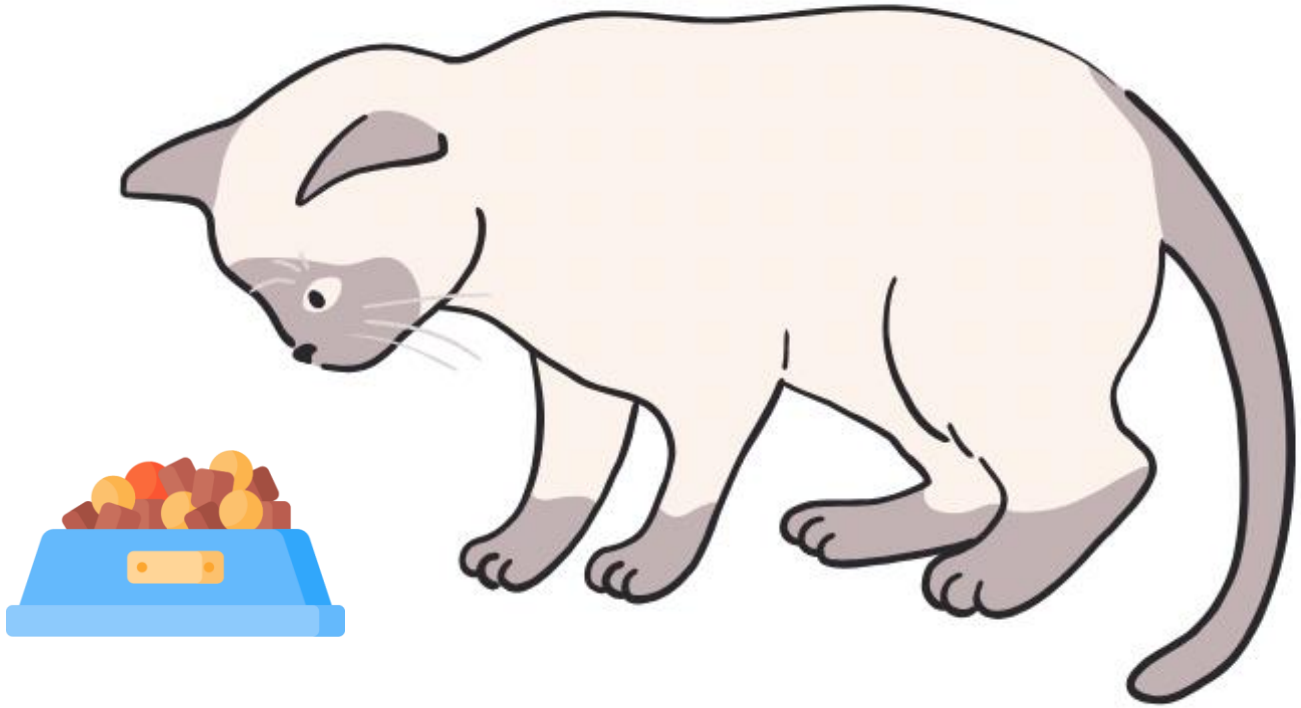
NFE Protein Fat



# Overall Conclusions




Thank You

# Materials & Methods

## Experimental Design: Foods

| Nutrient (% DM) | Low Protein | Low Fat | Low Carb |
|---|---|---|---|
| **Moisture** | 8.25 | 5.22 | 6.05 |
| **Dry Matter** | 91.75 | 94.78 | 93.95 |
| **Crude Protein** | 34.05 | 44.82 | 43.58 |
| **Crude Fat** | 20.05 | 13.61 | 20.33 |
| **Crude Fibre** | 4.80 | 5.06 | 5.00 |
| **Ash** | 6.87 | 7.81 | 7.66 |
| **Total Dietary Fibre** | 12.21 | 12.45 | 13.20 |
| **Nitrogen Free Extract**[1] | 34.23 | 28.70 | 23.43 |
| **Metabolizable Energy**[1$] **(kcal/kg DM)** | 4,261.97 | 3,907.22 | 4,247.88 |

[1]Using Crude Fibre; [$]Calculated using the Modified Atwater Equation
DM, dry matter

| | Low Protein | Low Fat | Low Carb |
|---|---|---|---|
| Starlite Peas | 19.79 | 17.81 | 6.80 |
| Oat Groats | 7.50 | 10.60 | 9.70 |
| Pea Fiber | 10.90 | 12.00 | 11.90 |
| Dry pal | 1.30 | 1.30 | 1.30 |
| Chicken Meal | 17.60 | 18.00 | 18.38 |
| HCPC | 0.50 | 7.70 | 8.00 |
| Dried Chicken | 1.10 | 17.10 | 14.50 |
| Egg Powder | 6.00 | 2.00 | 8.00 |
| Fresh Chicken | 20.00 | 5.00 | 8.00 |
| Liquid pal | 3.00 | 3.00 | 3.00 |
| Chicken Fat Category 3 | 6.80 | 2.20 | 6.00 |
| Herring Oil | 2.10 | 0.70 | 1.90 |
| Kelp | 0.30 | 0.50 | 0.40 |
| CPF Vitamin ADE | 0.05 | 0.08 | 0.05 |
| CPF Vitamin E | 0.15 | 0.15 | 0.10 |
| Choline Chloride | 0.30 | 0.20 | 0.23 |
| Sel-Plex NON GMO | 0.05 | 0.05 | 0.03 |
| NS Methionine | 0.25 | 0.05 | 0.05 |
| Biotin Premix NON-GMO | 0.15 | 0.10 | 0.15 |
| Potassium Chloride | 0.45 | 0.35 | 0.40 |
| Salt | 0.40 | 0.40 | 0.40 |

| | Body Condition | | Test Diet | | | P-Values | |
|---|---|---|---|---|---|---|---|
| | Lean | Obese | LP | LF | LC | BC | Diet |
| DFI (g/day) | 49.72 ±0.42$^{A}$ | 66.19 ±0.56$^{B}$ | 56.14 ±0.56$^{a}$ | 59.52 ±0.59$^{b}$ | 56.50 ±0.56$^{a}$ | <0.0001 | 0.0003 |
| DEI (kcal/day) | 192.19 ±1.76$^{A}$ | 255.05 ±2.34$^{B}$ | 218.47 ±2.32 | 220.42 ±2.34 | 225.37 ±2.39 | <0.0001 | 0.1076 |
| Protein Intake (g/d) | 18.84 ±0.64$^{A}$ | 25.08 ±0.86$^{B}$ | 17.53 ±0.43$^{c}$ | 25.30 ±0.62$^{b}$ | 23.13 ±0.56$^{a}$ | <0.0001 | <0.0001 |
| Fat Intake (g/d) | 31.82 ±1.15$^{A}$ | 42.23 ±1.52$^{B}$ | 40.18 ±1.06$^{c}$ | 28.46 ±0.73$^{b}$ | 43.06 ±1.11$^{a}$ | <0.0001 | <0.0001 |
| NFE Intake (g/d) | 5.01 ±0.17$^{A}$ | 6.67 ±0.23$^{B}$ | 5.51 ±0.13$^{c}$ | 6.88 ±0.17$^{b}$ | 5.09 ±0.12$^{a}$ | <0.0001 | <0.0001 |

# Database & Model Building

APPENDIX

Driving variables for modelling fasted glucose (mmol/L) and fasted insulin (pmol/L) included:

- PROC CORR procedure: continuous vs continuous
- Kruskal-Wallis test: categorical vs continuous variables
- PROC FREQ and Chi-Square test: categorical vs categorical variables
- Any X variables that were considered collinear ($P$ <0.05) were not considered for the same equation together.

3

# Database & Model Building

- PROC MIXED procedure was used to assess mixed models within SAS Studio.
- Univariate models with CHO (%ME) or Trade as driving variables
  - Followed by addition of driving variables to build **multivariate models**
- Cook's distance was utilized for detection of outliers

3

# Database & Model Building

## Model Assessment

- **Akaike information criteria (AICc)**
  - A lower AICc value was indicative of better fit.
- **Normality**
  - QQ plots, histogram, and via the Shapiro-Wilk test.

## Model Evaluation

**Mean Square Prediction Error (MPSE):** estimation of the overall prediction error
Decomposition of the RMSPE into error:

1) bias (ECT)
2) random disturbance
3) derivation of the regression slope from unity (ER) was conducted.

**Concordance correlation coefficient (CCC):** To determine the reproducibility inde

# Results: Body Fat Mass (kg) (Lean Cats Only)

## Univariate Models

| X Variable | Parameter | Estimate | P-Value |
|---|---|---|---|
| **NFE, % ME** | Intercept | 1.324 ± 0.19 | 0.0010 |
| | NFE | -0.0154 ± 0.005 | 0.0053 |
| **Fat, % ME** | Intercept | 0.154 ± 0.20 | 0.4739 |
| | Fat | 0.0216 ± 0.01 | 0.0011 |
| **Protein, % ME** | Intercept | 0.902 ± 0.43 | 0.0871 |
| | Protein | -0.0005 ± 0.01 | 0.9652 |

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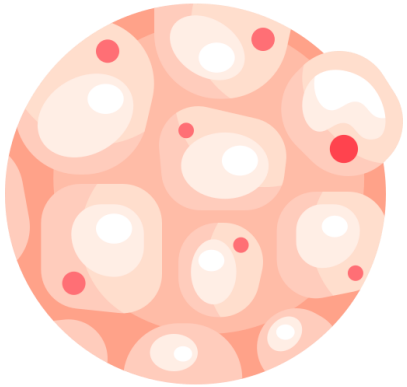
| **Protein, % ME** | Intercept | 0.902 ± 0.43 | 0.0871 |
| | Protein | -0.0005 ± 0.01 | 0.9652 |



# Results: Body Fat Mass (kg) (Lean Cats Only)

**Univariate Models**

**For every 1% increase of NFE (% ME) BFM is reduced by 0.0154 ± 0.005 kg.**

A 1% increase in fat (% ME) was determined to increase BFM by 0.0216 ± 0.01 kg.

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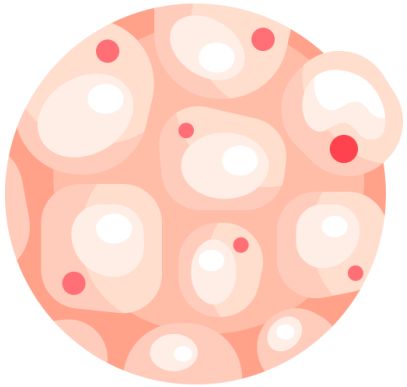



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