Glycemic Response in Thoroughbred Mares

by

Carey A. Williams

Thesis submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science

in

Animal and Poultry Science

David S. Kronfeld, Chairman

Larry A. Lawrence

E.A. Dunnington

August 9, 2000

Blacksburg, Virginia

Key Words: Horse, Glucose, Insulin, Dietary fat, Dietary fiber
Glycemic Response in Thoroughbred Mares

by
Carey A. Williams
Department of Animal and Poultry Science

(ABSTRACT)

The objective of this study is to determine if fat and fiber in a pasture supplement will be beneficial to the digestion and metabolism of the horse as compared to a concentrate high in sugar and starch. In both experiments, plasma concentrations of glucose and insulin following a meal were compared in Thoroughbred mares. In the first experiment, 12 pregnant and lactating mares were used in three different glycemic response tests to determine the effect of feeds on reproductively active mares. The mares were fed a typical pelleted concentrate (PC) three months before foaling and after foaling they were divided into two groups and fed a traditional sweet feed high in sugar and starch (SS), or a feed high in fat and fiber (FF). The feeds had similar DE and CP, but differed in fat (19, 32, and 166 g/kg DM, respectively) and NDF (199, 185, and 369 g/kg DM, respectively). For the second experiment, the same 12 mares (R mares) and 10 barren mares (B mares) were used in three different tests to determine the effects of the SS or FF feeds relating to season and reproductive stage. For each test, mares were placed in stalls and deprived of feed overnight. A series of blood samples was collected via a jugular catheter from 0 to 390 min after consumption of 1.82 kg of feed. Plasma was analyzed for glucose and insulin. Baseline values, peak values, increments and areas under the curve (AUC) were compared by ANOVA. For the first experiment glucose and insulin baseline values were similar for each diet and stage. Responses to PC did not differ between the two groups, indicating the groups were metabolically similar. Peak plasma glucose ($P < 0.001$) and insulin ($P < 0.001$) concentrations were higher in SS than in FF during both early and late lactation. Glucose ($P < 0.002$) and insulin ($P < 0.003$) AUCs were higher in SS than in FF during both early and late lactation. In the second experiment the baseline values for glucose and insulin were similar for both groups of R mares and B mares;
however, there were differences between the R and B mares. The peak glucose increment had significant differences or a trend for a difference for the main effects feed, pregnancy and season, and interactions feed by pregnancy and feed by season. The glucose AUC values obtained have a similar significance level the main effects and the interaction feed by pregnancy. When the peak insulin values are expressed as increments there is a difference for the main effects feed and pregnancy, but not the interactions. Insulin AUCs revealed also a significant or trend for a difference between main effects feed and pregnancy, and also for season, and the interaction feed by pregnancy. These results indicate that metabolic fluctuations are moderated by the replacement of sugar and starch with fat and fiber. This replacement may reduce the risk of certain digestive and metabolic disorders that have been linked to feeding meals of grain-based concentrates.

(Key Words: Horse, Glucose, Insulin, Dietary fat, Dietary fiber)
Acknowledgements

First of all I would like to thank my parents, Rich and Sue Williams. They have always been encouraging and supportive through everything I have done. Supporting a teenage girls love for horses is not an easy thing for parents to accept or support, but my parents have done an exceptional job, and I thank them for that.

I would also like to thank my committee members, Dr. David Kronfeld, chairman, Dr. Larry Lawrence, and Dr. Anne Dunnington, for all their help and support. Dr. Kronfeld, thank you for all your advice and guidance through all the tough times and data, also I thank you for making me a very strong and self-sufficient person. I would also like to acknowledge other faculty and staff that have helped me out through the course of my masters research and course work: Dr. Sklan, Dr. Splan, Dr. Jack. I would like to thank Louisa Gay for helping me out with my lab analysis on the Beckman and the RIA kits; without her I would have no data to report.

A special thanks goes to all the graduate students at the MARE center, Amy Ordakowski, Burt Staniar, Belinda Hargreaves, Kelly Malec-McConnell, and Bridgette Byrd; they have not only helped me with my research, but they were there as friends, guidance, and support. I especially want to thank Amy, she has been my mentor throughout my masters, which started with my first weekend trip to the MARE Center and extended through department seminars and is on going today. Amy has been a wonderful friend by being some sanity and a pair of ears when I needed them most. If I didn’t have Amy’s friendship I would have not enjoyed the last two years as much.

I would also like to acknowledge the staff at the MARE Center, Dr. Wendell Cooper, Dr. Janice Holland, Alvin Harmon, Bobbie Moriarty, Bill Helsel, Scott Gerbich, and Tim Parmley. They have helped me out with research when extra hands are needed, and were sometimes there just to listen to me complain. I especially would like to thank
Janice; she not only helped me through my research, but also was there to steer me in the right direction when I would go astray.

My friends also deserve special notice; Karen Cizek, Eve Miller, Ann-Marie Hancock, and Travis Groves learned to stick with me during the times where I seemed to fall off the planet, they knew to stay close and not to ever give up. Other members of my family; brother, Matt Williams, grandma, Joe McCoy, grandma, Ann Williams, aunts, uncles, and cousins, need special thanks for sticking with me and keeping interested especially when things got too busy for me to take time to write or call. Last, but certainly not least I would like to thank my boyfriend, Patrick. I know being this close to someone who is going through the process of obtaining a masters degree isn’t easy, I just wanted to say thank you for hanging in there and being patient with me when things got a bit rough.
Table of Contents

ABSTRACT ................................................................................................................. ii
ACKNOWLEDGEMENTS ......................................................................................... iv
TABLE OF CONTENTS ............................................................................................... vi
LIST OF TABLES ....................................................................................................... viii
LIST OF FIGURES .................................................................................................... ix
LIST OF APPENDIX TABLES ................................................................................... x
LIST OF APPENDIX FIGURES .................................................................................. xiii

INTRODUCTION ........................................................................................................ 1
LITERATURE REVIEW

   Pasture Supplementation ....................................................................................... 3
   Added fiber ........................................................................................................... 5
   Added fat ............................................................................................................. 6
   Glycemic response ............................................................................................... 8
   Human use .......................................................................................................... 9
   Equine use ......................................................................................................... 10
   Insulin resistance ............................................................................................. 12
LITERATURE CITED ................................................................................................. 15
TABLES .................................................................................................................... 21
FIGURES .................................................................................................................. 22
OBJECTIVES ............................................................................................................. 25

JOURNAL ARTICLE 1

   Abstract .............................................................................................................. 26
   Introduction ....................................................................................................... 27
   Materials and Methods ..................................................................................... 27
   Results .............................................................................................................. 29
   Discussion ....................................................................................................... 30
C.A. Williams  Table of Contents  vii

Implications.......................................................................................... 33
Literature Cited..................................................................................... 34
Tables................................................................................................... 37
Figures.................................................................................................. 39

JOURNAL ARTICLE 2

Abstract.................................................................................................. 42
Introduction........................................................................................... 43
Materials and Methods......................................................................... 43
Results.................................................................................................. 45
Discussion.............................................................................................. 47
Implications........................................................................................... 50
Literature Cited..................................................................................... 51
Tables................................................................................................... 53
Figures.................................................................................................. 56

APPENDIX TABLES.............................................................................. 60
APPENDIX FIGURES............................................................................ 78
VITA...................................................................................................... 87
List of Tables

Literature Review Tables

Table 1. The glycemic index (GI) of food based on glucose as the reference (i.e. 100) ........................................................................................................ 21

Journal Article 1 Tables

Table 1. Ingredient composition (%) of the sugar and starch (SS) and fat and fiber (FF) feeds .................................................................................... 37
Table 2. Nutrient composition of the sugar and starch (SS), fat and fiber (FF) and the pelleted concentrate (PC) feed as analyzed in the DHI Forage Testing Laboratory (Ithaca, NY) ........................................................................ 38

Journal Article 2 Tables

Table 1. Ingredient composition (%) of the sugar and starch (SS) and fat and fiber (FF) feeds .................................................................................... 53
Table 2. Nutrient composition of the sugar and starch (SS) and fat and fiber (FF) feed as analyzed in the DHI Forage Testing Laboratory (Ithaca, NY) ........................................................................ 54
Table 3. Nutrient composition of the pastures prior to each trial date as analyzed in the Dairy One Forage Testing Laboratory (Ithaca, NY) ........................................................................ 55
List of Figures

Literature Review Figures

Figure 1. Feeding-fasting cycle (adapted from Kronfeld, 1996) .......... 22
Figure 2. Carbohydrate fractions and their metabolism (adapted from Kronfeld, 1996) ................................................................. 23
Figure 3. Proposed model for the role of insulin resistance, pancreatic B-cell function and plasma free fatty acids (adapted from Wolever, 2000) .................................................................................. 24

Journal Article 1 Figures

Figure 1. Mean concentration of the plasma glucose (bars) and insulin (solid line) for twelve mares fed the pelleted concentrate (PC) during late gestation. The two groups of mares were combined to show an illustration of the glucose and insulin curve .......... 39
Figure 2. Peak plasma glucose (A) and glucose area under the curve (B) in mares fed the pelleted concentrate (PC), a feed high in sugar and starch (SS) and feed high in fat and fiber (FF) during early lactation (1) and late lactation (2) .................................................... 40
Figure 3. Peak plasma insulin (A) and area under the curve (B) for insulin in mares fed the pelleted concentrate (PC), a feed high in sugar and starch (SS) and feed high in fat and fiber (FF) during early lactation (1) and late lactation (2) .................................................. 41

Journal Article 2 Figures

Figure 1. Plasma glucose increments (a) (baseline subtracted from peak), during the three different seasons, barren (B) and reproductive (R) mares fed a feed with sugar and starch (SS) or a feed with fat and fiber (FF). The effects of reproductive stage on the glucose increment for B mares is subtracted from the R mares (b) ......... 56
Figure 2. Glucose area under the curve (a) for reproductive (R) and barren (B) mares on a feed with sugar and starch (SS) and a feed with fat and fiber (FF), and the effect of reproductive stage on plasma glucose AUC (b)………………………………………………………………………………… 57

Figure 3. Plasma insulin increments (a) (baseline subtracted from peak) during the three different seasons, barren (B) and reproductive (R) mares fed a feed with sugar and starch (SS) or a feed with fat and fiber (FF). The effects of reproductive stage on the insulin increment for B mares is subtracted from the R mares (b)………… 58

Figure 4. Insulin area under the curve (a) for reproductive (R) and barren (B) mares on a feed with sugar and starch (SS) and a feed with fat and fiber (FF), and the effect of reproductive stage on plasma insulin AUC (b)………………………………………………………………………………… 59
**List of Appendix Tables**

Table 1. Glucose concentration (mg/dL) for each sample time of mares fed a typical pelleted concentrate feed (PC) during late gestation. Data for Journal Article 1 ................................................................. 60

Table 2. Insulin concentration (mIU/L) for each sample time of mares fed a typical pelleted concentrate feed (PC) during late gestation. Data for Journal Article 1 ................................................................. 61

Table 3. Glucose concentration (mg/dL) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during early lactation. Data for Journal Article 1 ................................................................. 62

Table 4. Insulin concentration (mIU/L) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during early lactation. Data for Journal Article 1 ................................................................. 63

Table 5. Glucose concentration (mg/dL) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during late lactation. Data for Journal Article 1 ................................................................. 64

Table 6. Insulin concentration (mIU/L) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during late lactation. Data for Journal Article 1 ................................................................. 65

Table 7. Glucose concentration (mg/dL) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during mid gestation. Data for Journal Article 2 ................................................................. 66
Table 8. Insulin concentration (mIU/L) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during mid gestation. Data for Journal Article 2……………………………………………………………………………….. 67

Table 9. Glucose concentration (mg/dL) for each sample time of barren mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during winter. Data for Journal Article 2……………………………………………………………………………….. 68

Table 10. Insulin concentration (mIU/L) for each sample time of barren mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during winter. Data for Journal Article 2……………………………………………………………………………….. 69

Table 11. Glucose concentration (mg/dL) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during late gestation. Data for Journal Article 2……………………………………………………………………………….. 70

Table 12. Insulin concentration (mIU/L) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during late gestation. Data for Journal Article 2……………………………………………………………………………….. 71

Table 13. Glucose concentration (mg/dL) for each sample time of barren mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during spring. Data for Journal Article 2……………………………………………………………………………….. 72

Table 14. Insulin concentration (mIU/L) for each sample time of barren mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during spring. Data for Journal Article 2……………………………………………………………………………….. 73
Table 15. Glucose concentration (mg/dL) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during early lactation.
Data for Journal Article 2................................................................. 74

Table 16. Insulin concentration (mIU/L) for each sample time of mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during early lactation.
Data for Journal Article 2................................................................. 75

Table 17. Glucose concentration (mg/dL) for each sample time of barren mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during summer.
Data for Journal Article 2................................................................. 76

Table 18. Insulin concentration (mIU/L) for each sample time of barren mares fed a sugar starch (SS) feed or a fat and fiber (FF) feed during summer.
Data for Journal Article 2................................................................. 77
List of Appendix Figures

Figure 1. Plasma glucose and insulin concentration-time curve for mares fed a typical pelleted concentrate (PC) during late gestation. Data from tables 1 and 2……………………………………………………………………...… 78

Figure 2. Plasma glucose and insulin concentration-time curve for mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during early lactation. Data from tables 3 and 4………………………………….…….. 79

Figure 3. Plasma glucose and insulin concentration-time curve for mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during late lactation. Data from tables 5 and 6………………………………………... 80

Figure 4. Plasma glucose and insulin concentration-time curve for mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during mid gestation. Data from tables 7 and 8………………………………………... 81

Figure 5. Plasma glucose and insulin concentration-time curve for barren mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during winter. Data from tables 9 and 10………………………………………... 82

Figure 6. Plasma glucose and insulin concentration-time curve for mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during late gestation. Data from tables 11 and 12………………………………………... 83

Figure 7. Plasma glucose and insulin concentration-time curve for barren mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during spring. Data from tables 13 and 14………………………………………... 84
Figure 8. Plasma glucose and insulin concentration-time curve for mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during early lactation. Data from tables 15 and 16. 85

Figure 9. Plasma glucose and insulin concentration-time curve for barren mares fed a sugar and starch feed (SS) and a fat and fiber feed (FF) during summer. Data from tables 17 and 18. 86