BARD

FINAL REPORT
PROJECT NO. US-2201-92

Influence of Ruminant Starch Degradability on Performance of High Producing Dairy Cows

J.T. Huber, J. Miron, D. Ben-Ghedalia

הספריה המרכזית
למדעי החקלאות
בית דגן

1998

Final BARD Research Report of The University of Arizona

BARD Project No. US-2201-92R

**Title: Influence of Ruminal Starch Degradability
on Performance of High Producing Dairy Cows**

()

Submitted by: J. T. Huber
Department of Animal Sciences
University of Arizona
205 Shantz - PO Box 210038
Tucson, Arizona 85721-0038

Project's starting date: January, 1994

Project's ending date: June, 1997

יחידת המחקר
מרכזי החקלאות
בית דגן

Signature:

Dr. J. T. Huber, Principal USA Investigator

630.72
BARD Hub
2nd copy

Final BARD Research Report of The Israeli Group

BARD Project No. US-2201-92R

**Title: Influence of Ruminant Starch Degradability on the
Digestibility by Dairy Cows of Dietary Monosaccharide
Components.**

Submitted By: Joshua Miron and Daniel Ben-Ghedalia

**Metabolic Unit, Institute of Animal Science,
Agricultural Research Organization, The Volcani Center,
P.O.Box 6, Bet Dagan, 50250, Israel.**

Project's starting date: January, 1994.

Project's ending date: June 1997.

Signature: JOSHUA MIRON

Dr. J. Miron, Principal Israeli Copartner.

Table of Contents

Title Page with Signature (USA)	i
Title Page with Signature (Israel)	ii
Abstract	1
Objectives	1
Relevant Data, Methodology, Results and Discussion	2
Cooperation Between the Arizona and Israeli Groups	3
Evaluation of Research Achievement	3
Conclusions	5
List of Publications	5

Abstract: This research project entitled "Influence of Ruminant Starch Degradability on Performance of High Producing Dairy Cows" had the following objectives: a) Determine effects of feeding varying amounts of ruminally degradable starch (RDS) on efficiency of milk and milk protein production; and 2) Investigate digestive and metabolic mechanisms relating to lactation responses to diets varying in ruminal and total starch degradability. Four lactation studies with high producing cows were conducted in which steam-flaked (~ 75% RDS) was compared with dry-rolled sorghum (~ 50% RDS) grain. All studies demonstrated increased efficiency of conversion of feed to milk (FCM/DMI) and milk protein as amount of RDS in the diet increased by feeding steam-flaked sorghum. As RDS in diets increased, either by increased steam-flaked sorghum, grinding of sorghum, or increasing the proportion of wheat to sorghum, so also did ruminal and total tract digestibilities of starch and neutral-detergent soluble (NDS) carbohydrate. Despite other research by these two groups of workers showing increased non-ammonia N (NAN) flowing from the rumen to the duodenum with higher RDS, only one of the present studies showed such an effect. Post-absorptive studies showed that higher dietary RDS resulted in greater urea recycling, more propionate absorption, a tendency for greater output of glucose by the liver, and increased uptake of alpha-amino nitrogen by the mammary gland. These studies have shown that processing sorghum grain through steam-flaking increases RDS and results in greater yields and efficiency of production of milk and milk protein in high producing dairy cows.

Objectives:

- a) Determine effects of feeding varying amounts of ruminally degradable starch on efficiency of milk and milk protein production.
- b) Investigate digestive and metabolic mechanisms relating to lactation responses to diets varying in ruminal and total starch degradability.

Even though a different metabolic trial at Arizona was conducted in lieu of that originally proposed (which was not feasible to complete because of laboratory problems), the trial described in this report was in line with the objectives of the project. Because of a lack of facilities, the lactation trial proposed by Israel was not conducted, but the four lactation

trials performed by Arizona allowed for accomplishment of the objective with respect to the lactation studies.

Overall, the objectives proposed in the original project were very well accomplished, and data generated has great practical significance (as is evident by a large-scale acceptance of steam-flaking of sorghum and other grains in the western U.S.), as well as making a cutting-edge scientific contribution (particularly the post-absorptive studies).

Relevant Data, Methodology, Results and Discussion:

Each of the individual experiments is written up separately detailing methodology used, results obtained, and discussion of said results. They are listed in the following order:

- 1) Lactation studies
 - a) Comparison of Sorghum Grain Processed at Different Densities and Barley for Lactating Cows (Arizona)
 - b) Effect of Substituting Steam-Flaked Sorghum for Concentrate on Lactation and Digestion in Dairy Cows (Arizona)
 - *c) Effect of Enzyme Treatment or Steam-Flaking of Sorghum Grain on Lactation and Digestion in Dairy Cows
 - d) Response of Lactating Dairy Cows to Various Densities of Sorghum Grain - This project is substituted in lieu of the lactation trial originally proposed by the Israeli Group. (Arizona)
- 2) Trials pertaining to site of digestion, NAN flow to the duodenum, forage CW monosaccharide components, and metabolism of absorbed nutrients
 - a) Effect of Changing the Proportion Wheat:Sorghum in Dairy Cow Rations on Carbohydrate Digestibility and NAN Flow to the Small Intestine (Israel)
 - b) Effect of Protein Source and Steam-Flaked Sorghum on Rumen Fermentation and Nutrient Passage to the Duodenum of Dairy Cows (Arizona). This study is substituted in lieu of one testing varying levels of sorghum which was not completed because of problems encountered in the laboratory.

- c) Digestibility by Dairy Cows of Monosaccharide Components in Diets Containing Either Ground Sorghum or Sorghum Grain Treated with Sodium Hydroxide (Israel)
- d) Absorption and Metabolism of Absorbed Nutrients by Gut, Liver, and Mammary Tissues (Arizona)
 - 1) Net Absorption, Hepatic Metabolism, Splanchnic Output, and Mammary Uptake of Glucose, L-Lactate and Volatile Fatty Acids in Lactating Dairy Cows Fed Dry-Rolled or Steam-Flaked Sorghum Grain
 - 2) Visceral, Hepatic, and Mammary Nitrogen Metabolism in Lactating Dairy Cows Fed Dry-Rolled or Steam-Flaked Sorghum Grain (Please see note following number 4 in "List of Publications".

Cooperation Between the Arizona and Israeli Groups:

Meetings were held between the principal investigators of the projects at scientific meetings in which plans were discussed and results were reviewed pertaining to the various studies. The first and second annual reports were generated cooperatively and ideas were shared throughout the study. As the result of this proposal, an Israeli scientist (Dr. Haim Tagari, who was not a member of the original research team, but was added later) performed a Sabbatical Leave with the Arizona Group, during which he contributed greatly to the "Post-Absorptive" studies at Arizona.

Evaluation of Research Achievement:

Objective 1 was successfully achieved in this project. Three of the four lactation trials demonstrated conclusively that as RDS in the diet increased through steam-flaking of sorghum grain, the efficiency of milk yield (FCM/DMI) also increased. In two of the studies (by Santos et al.), the primary effect which resulted in increased efficiency was a reduction in DMI and maintenance of milk yield at a similar level. In the other two studies (Chen et al.), milk yield increased without a concomitant increase in DMI in one (resulting in greater efficiency), but in the other DMI was increased, as was milk yield. All studies demonstrated

a dramatic effect of steam-flaking in allowing the animal to extract more energy from sorghum grain.

Milk protein content and production were increased through steam-flaking in two of the lactation studies (Chen et al.). In the two studies of Santos et al., efficiency of conversion of DM and dietary protein to milk protein increased as RDS in diets increased from about 13% of DM to 22%. The main fraction of milk protein that increased because of higher RDS in the diet was casein (Santos et al.). In one of the studies (when buffers were not added), a decrease in milk and milk protein yields was observed at about 25% of DM as RDS, suggesting that increased RDS above about 22% of DM appeared more detrimental than beneficial.

Pertaining to Objective 2, six of seven studies showed that diets which contained greater amounts of RDS resulted in higher total tract digestibilities of starch or NDS carbohydrate. Even though site of more starch or NDS carbohydrate digestion was shifted to the rumen with increased RDS, it did not result in greater synthesis of microbial protein in the rumen (as was expected and was shown in previous research at Arizona) or flow of NAN to the duodenum in two studies, but in one comparison between ground and NaOH-treated sorghum grain, an increase in NDS carbohydrate resulted in greater NAN flow to the duodenum.

Total tract digestibility of neutral detergent fiber was generally lower in diets with higher RDS, even though these effects were not as pronounced when the increased RDS resulted from steam-flaking of sorghum grain, rather than increasing RDS by substitution of wheat for sorghum or by NaOH treatment of sorghum grain.

Lower RDS in diets generally resulted in lower total VFA in the rumen and a higher ruminal pH, even though results were not always consistent. Urea addition to a diet relatively high in RDS (because of steam-flaking of sorghum grain) caused higher ruminal NH_3 concentrations, total VFA, as well as amounts of acetate, propionate, and butyrate, compared with a low RDS diet. Acetate:propionate ratios were unchanged in this study.

The post-absorptive studies reported herein demonstrated that a diet high in RDS (because of steam-flaking of sorghum grain) increased the absorption of propionate and energy from VFA from the gut, but not any of the other major metabolites. However, the

increased RDS did stimulate greater recycling of urea-N to the gastrointestinal tract. Furthermore, there was a tendency for greater hepatic output of glucose. This effect was accompanied by more alpha-amino nitrogen being taken up by the mammary gland of the cow.

Patents: None

Conclusions:

From the lactation studies, steam-flaking of sorghum grain to a density of approximately 360 g/L resulted in increased milk and milk protein yields, as well as efficiencies of conversion of feed DM or dietary protein to milk and milk protein. These increases were associated with higher ruminal and total tract starch digestibilities; thus, an extraction by the cow of more total energy from the grain was accomplished. These findings support earlier studies by the Arizona group that steam-flaking increases NE_L of sorghum grain about 20% (1.84 to 2.20 Mcal/kg). Steam-flaking also increased N conservation by causing greater urea recycling to the gut. Moreover, a shift in the site of digestion of the grain stimulated more propionate available for glucose synthesis by the liver and a greater uptake of amino nitrogen by the mammary gland.

Grinding compared with NaOH-treatment of sorghum grain showed an advantage for dairy cows fed the ground sorghum because of greater starch digestibility of the ground sorghum. Increasing RDS by substituting wheat for sorghum grain in cows did not show any advantage for the high-wheat group.

List of Publications:

1. Chen, K.H., J.T. Huber, C.B. Theurer, J. Simas, F. Santos, S.C. Chan and R.S. Swingle. 1995. Effect of substituting steam-flaked sorghum for concentrate on lactation and digestion in dairy cows. *J. Dairy Sci.* 78:362-367.
2. Chen, K.H., J.T. Huber, J. Simas, C.B. Theurer, P. Yu, S.C. Chan, F. Santos, Z. Wu, and R.S. Swingle. 1995. Effect of enzyme treatment or steam flaking of sorghum grain on lactation and digestion in dairy cows. *J. Dairy Sci.* 78:1721-1727.
3. Chen, K.H.. 1994. Effect of Grain Processing on Lactational Performance and Nutrient Utilization in Dairy Cows. Chapter 6: Effect of protein source and steam-

- flaked sorghum on rumen fermentation and nutrient passage to the duodenum of dairy cows. Ph.D. Diss., Univ. Arizona, Tucson.
4. Delgado-Elorduy, A. 1997. Splanchnic and Mammary Nitrogen Metabolism in Dairy Cows Fed Differently Processed Corn and Sorghum Grain. Chapter 3: Visceral, hepatic, and mammary nitrogen metabolism in lactating dairy cows fed dry-rolled or steam-flaked sorghum grain. Ph.D. Diss., Univ. Arizona, Tucson. (This item is a work-in-progress, and will be sent to you at a later date.)
 5. Miron, J., D. Ben-Ghedalia, and R. Solomon. 1997. Digestibility by dairy cows of monosaccharide components in diets containing either ground sorghum or sorghum grain treated with sodium hydroxide. *J. Dairy Sci.* 80:144-151.
 6. Miron, J., R. Solomon, I. Bruckental, and D. Ben-Ghedalia. 1996. Effect of changing the proportion, wheat:sorghum in dairy cow rations on carbohydrate digestibility and NAN flow to the intestine. *Anim. Feed Sci. Tech.* 57:75-86.
 7. Sadik, M. 1997. Post-Absorptive Energy Metabolism of Lactating Dairy Cows Fed Differently-Processed Corn and Sorghum Grains. Chapter 3: Net absorption, hepatic metabolism, splanchnic output, and mammary uptake of glucose, L-lactate and volatile fatty acids in lactating dairy cows fed dry-rolled or steam-flaked sorghum grain. Ph.D. Diss., Univ. Arizona, Tucson.
 8. Santos, F.A.P., J.T. Huber, C.B. Theurer, R.S. Swingle., and J.M. Simas. 1997. Response of lactating dairy cows to various densities of sorghum grain. *J. Anim. Sci.* 75:1681-1685.
 9. Santos, F.A.P., J.T. Huber, C.B. Theurer, R.S. Swingle, Z. Wu, J.M. Simas, K.H. Chen, S.C. Chan, J. Santos, and E.J. DePeters. 1997. Comparison of sorghum grain processed at different densities and barley for lactating dairy cows. *J. Dairy Sci.* (in press).
 10. Sadik, M., O. Lozano, B. Theurer, T. Huber, A. Delgado-Elorduy, A. Alio, G. Ghenniwa, and J. Simas. 1997. Net absorption and mammary uptake of VFA, BHBA and energy by lactating dairy cows fed diets containing 40% corn or sorghum grain processed as steam-flaked (SF), steam-rolled (SR) or dry-rolled (DR). *J. Dairy Sci.* 80(Suppl. 1):212.(Abstr.)
 11. Delgado-Elorduy, A., C.B. Theurer, J.T. Huber, M. Sadik, A. Alio, O. Lozano, H. Tagari, P. Cuneo, D. DeYoung, G. Ghenniwa, L. Nussio, J. Santos, and C. Nussio. 1996a. Visceral and hepatic nitrogen metabolism in lactating dairy cows fed steam-flaked or dry-rolled sorghum grain diets. *J. Dairy Sci.* 79(1):178.(Abstr.)
 12. Miron, J., D. Ben-Ghedalia, and R. Solomon. 1996. Digestibility by dairy cows of monosaccharide components in diets containing either ground or sodium hydroxide treated sorghum grain. *J. Dairy Sci.* 79(Suppl. 1):212.(Abstr.)
 13. Sadik, M., C.B. Theurer, J.T. Huber, A. Delgado-Elorduy, A. Alio, O. Lozano, H. Tagari, P. Cuneo, D. DeYoung, G. Ghenniwa, J. Simas, P. Yu, and F. Santos. 1996a. Net absorption and hepatic metabolism of glucose and L-lactate in lactating dairy cows fed diets containing 40% dry-rolled or steam-flaked sorghum grain. *J. Dairy Sci.* 79(1):178.(Abstr.)

14. Miron, J., R. Solomon, I. Bruckental, and D. Ben-Ghedalia. 1995. Effect of changing the ratio, wheat:sorghum in dairy cow TMR on NDF-carbohydrate digestibility and NAN flow to the intestine. *J. Dairy Sci.* 78(Suppl. 1):115.(Abstr.)
15. Santos, F.A.P., J.T. Huber, C.B. Theurer, J. Santos, L.G. Nussio, J.M. Simas, P. Yu, J. Aquino, H. Mena, M. Tarazon, Z. Keister, and F. Souza. 1995. Response of high producing dairy cows to different protein sources when fed steam-flaked sorghum diets. *J. Dairy Sci.* 78(Suppl. 1):294.(Abstr.)
16. Chen, K.H., J.T. Huber, C.B. Theurer, Z. Wu, S.C. Chan, J. Simas, P. Yu, J. Valera, C. Fontes, and A. Ghenniwa. 1994. Effect of protein degradability in dairy cows fed flaked sorghum on rumen fermentation. *J. Anim. Sci.* 72(Suppl. 1):388.(Abstr.)
17. Santos, F.A.P., J.T. Huber, C.B. Theurer, R.S. Swingle, Z. Wu, J.M. Simas, K.H. Chen, S.C. Chan, C. Fontes, and P. Yu. 1994. Response of high producing dairy cows to varying densities of sorghum grain. *J. Anim. Sci.* 72(Suppl. 1):234.(Abstr.)
18. Santos, F.A.P., J.T. Huber, C.B. Theurer, R.S. Swingle, Z. Wu, J.M. Simas, K.H. Chen, S.C. Chan, C. Fontes, and P. Yu. 1994. Comparison of sorghum grain processed at different densities and barley for lactating dairy cows. *J. Anim. Sci.* 72(Suppl. 1):234.(Abstr.)