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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1032397

Project Title

Developing tools to improve sustainability in Medium and Small-Sized Farms: Using body size measures from computer vision and AI to evaluate influences of heifer development on cow efficiency.

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** ACTIVE
Funding Source NIFA Non Formula	**Grant Year** 2024
Grant No. 2024-67023-42503	**Cumulative Award Amt.** $649,999.00
Proposal No. 2023-08088	**Multistate No.** (N/A)
Project Start Date Jul 15, 2024	**Project End Date** Jul 14, 2028
Program Code [A1601] Agriculture Economics and Rural Communities: Small and Medium-Sized Farms	

Project Director

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Recipient Organization

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Performing Department

(N/A)

Non Technical Summary

Beef cattle production, or more specifically cow-calf production, accounts for nearly half of the value of products from small and medium-sized farms in the United States. Indeed, cow-calf operations with less than 100 cows account for more than 90% of all cow-calf operation in the United States and the average national beef herd size is 44 cows. Cow-calf production systems are generally less labor intensive than other on-farm enterprises, which probably makes this production system attractive to most small and medium-sized producers (Cash, 2002). Identifying efficient cows and implementing heifer development strategies that improve cow lifetime efficiency could therefore largely enhance economic efficiency and overall sustainability of small and medium-sized farms. We present an interdisciplinary team who researches energy metabolism, animal management, genetics, and robotic vision. Our objective is to develop a digital system that simultaneously improves production, enhances farm profitability, and provides small and medium-

sized farmers with a climate smart tool to address climate change by determining individual differences in feed efficiency of beef cows using the first principles of animal energetics and advances in robotic vision. The use of computer-generated surface area and volume data will allow us in real-time to predict the metabolic needs of different classes of cattle across various contexts. Overall, these data will have transformative impacts in optimizing animal management, nutrition and breeding, because direct measures of the primary factors that drive animal efficiency will be used to discover all new predictive equations and technologies developed from this work.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	25%
Applied	75%
Developmental	0%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
302	3399	1010	50%
302	3399	1000	40%
302	3399	1070	10%

Knowledge Area

[302] Nutrient Utilization in Animals

Subject Of Investigation

[3399] Beef cattle, general/other

Field Of Science

[1010] Nutrition and metabolism

[1000] Biochemistry and biophysics

[1070] Ecology

Keywords

Artificial Intelligence; Cow; Computer Vision; Efficiency

Goals / Objectives

Our objective is to develop a digital system that simultaneously improves production, enhances farm profitability, and provides small and medium-sized farmers with a climate smart tool to address climate change by determining individual differences in feed efficiency of beef cows using the first principles of animal energetics and advances in

robotic vision. The use of computer-generated surface area and volume data will allow us in real-time to predict the metabolic needs of different classes of cattle across various contexts. Overall, these data will have transformative impacts in optimizing animal management, nutrition and breeding, because direct measures of the primary factors that drive animal efficiency will be used to discover all new predictive equations and technologies developed from this work.

Project Methods

Heifers will be housed across 8 partially covered pens. Developmental heifers will be enrolled into the experiment in groups of 12 when they achieve a body weight of about 204 kg. In a 2-week period immediately prior to enrollment in the experiment, heifers will be acclimated to close human contact, trained to indirect calorimeters, vaccinated against respiratory and clostridial diseases, and treated for internal parasites. After enrolling the first group into the experiment, subsequent groups of heifers (initial body weight = 204 kg) will be enrolled every 14 days to facilitate measures of maintenance energy requirements using indirect calorimetry. Measures of surface area using our cattle scanner and a surface area integrator will be collected on each animal at the beginning of the experiment and when heifers weigh 306 and 408 kg, respectively. Measures of body weight will be measured on the whole animal when body weight estimates from front-end weight are within 23 kg of the target weight and measures will be collected when each cohort has an average weight of 204, 306 and 408 kg.Individual measures of maintenance energy expenditure will be obtained in small, medium and large heifers (e.g., 204, 306 and 408 kg body weight, respectively) by fasting animals for 96 hours prior to collection of respired air using open-circuit calorimetry. Measures of maintenance energy expenditure will be collected across two 24-hour periods. After each intermediate measure of maintenance energy requirement, cattle will be placed back on feed using the limited maximum intake protocol described Xiong et al. (1991) that has been used by our group in the past (Petzel et al., 2021). After heifers achieve a body weight of 408 kg, final measure of maintenance energy requirements will be collected, and heifers will be placed back on feed for a 14-day period prior initiating estrus synchronization and artificial insemination.At 240 days of gestation, maintenance energy requirements will be measured again using open-circuit calorimetry; however, maintenance energy will be determined by feeding heifers to 80% or 40% of predicted maintenance energy requirements (NASEM, 2016) across two 10-day periods (e.g., 80% of predicted maintenance energy requirements from gestational day 240 to 250, and 40% of predicted maintenance energy requirements from gestational day 250 to 260). Methods used for indirect calorimetry and energy and nutrient balance will be similar to those previously described by PI Brake's lab (Petzel et al., 2019, 2021; Acharya et al., 2023).Maintenance energy requirements determined in gestating females will be corrected for energy requirements of the gravid uterus using current models (NASEM, 2016) and extrapolating measures of retained energy per kg of feed (dry matter basis) consumed to the y-intercept to calculate maintenance energy requirements (Kleiber, 1975; NRC, 1981). This approach to measure maintenance energy requirements will be repeated again beginning 30 days after parturition. Measures of maintenance energy requirements will also include energy requirements for lactation by measuring milk output for 2 days preceding measures of indirect calorimetry. Milk will be collected using a portable vacuum milker every 12 hours and fed to each cow's calf after the milk output has been measured and samples are collected for determination of fat, protein, solids-not-fat, milk urea-nitrogen and somatic cell counts. Calves will be removed from the cow 12 hours prior to beginning measures of milk production and returned to its cow after the last milking. Measures of maintenance energy requirements will also be collected at gestational day 240 in heifers that calve and achieve a subsequent pregnancy using the same techniques. Measures of calf birth weight, and weaning weight will be recorded.To better define the relationship between surface area, volume, feed efficiency and feed intake in cattle, we will feed each pen of developmental heifers either a grain- (e.g., 43% corn grain, 23% dried distillers' grains, 20% corn silage, 12% ground hay, 2% vitamins and minerals) or forage- (e.g., 56% ground hay, 22% distillers' grains, 20% corn silage, 2% vitamins and minerals) based diet until a body weight of 306 kg is achieved. Subsequently, half the pens that received a grain-based diet during the initial phase of the experiment will be provided a forage-based diet from 306 kg of body weight to 408 kg of body weight, and the other half of cattle housed in pens receiving a grain-based diet will continue to be provided a grain-based diet until the end of the experiment. Alternatively, half of the pens that received a forage-based diet during the initial phase of the experiment will be provided a grain-based diet from 306 kg of body weight to 408 kg of body weight, and the other half

of cattle housed in pens receiving a forage-based diet in the initial phase of the experiment will be provided a forage-based diet until the end of the experiment. Thus, dietary treatments will be delivered across pens in a 2 × 2 factorial design. Measures of feed efficiency will be collected daily from daily measures of individual intake of each animal together with daily estimates of weight gain. Additionally, rates of weight gain will also be determined by collecting complete body weights every 28 days together with measures of surface area using our scanner during the experiment.Measures of intake will be determined in gestating and post-parturient females (i.e., after the developmental heifer stage) by feeding the same forage-based diet that was fed during the heifer development stage (2.5 Mcal ME/kg DM). Measures of intake will be accomplished by placing gestating and post-parturient females into the same partially covered pens (n = 12 per pen) at the University of Missouri Beef Research and Teaching Center with semi-autonomous individual feed monitoring and front-end weight systems (GrowSafe Systems, Alberta, CA) for a 14-day period prior to each measure of surface area, volume and maintenance energy requirements in the gestation and the post-parturient period that were described in Goal 1.The 96 cattle used in Goals 1 and 2 will be deeply phenotyped using camera surface area, post-slaughter hide surface area, volume, maintenance energy expenditure directly determined by open-circuit calorimetry, daily feed intake, and daily weight. We will also genotype (i.e., DNA test) these 96 cattle using Gencove's low-pass sequencing approach (Li et al., 2020). We will search for pathogen sequences that may be present in the sample (Whitacre et al., 2015), that may be indicative of infection differences between the animals. This unmapped reads metagenomic approach can either be implemented using Gencove's pipeline or in-house analysis using software such as PAIPline (Andrusch et al., 2018).We will identify the 4 animals with the largest positive residuals, 4 animals with the largest negative residuals, and 4 animals with the smallest residuals. Whole blood will be sampled for all 96 cattle, but Total RNA Stranded Library (rRNA depletion) libraries will only be prepared for the 12 selected cattle. RNA-seq libraries will be prepared and sequenced at the University of Missouri DNA Core .?We will combine these 3D data with previously completed datasets from University of Missouri USDA-funded projects to estimate genetic correlations between surface area, volume, and surface area-to-volume ratio with various production traits. Genetic correlations will be estimated. Four-dimensional scan data will be fit in bivariate models with feed intake (n = 11,494), average daily gain (n = 11,494), carcass weight (n = 16,718), ribeye area (n = 5,224), fat thickness (n = 5,224), marbling (n = 5,224), body weight (n = 11,494), hair shedding (n = 12,000), Bovine Respiratory Disease status (n = 2,074), pelvic area (n = 5,000), and heifer pregnancy (n = 5,000).