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An integrated multidisciplinary approach to improving the reproductive efficiency of seasonal calving beef cow herds in Ireland - 'BEEFCOW'

Key external stakeholders:

Livestock industry, Animal nutrition, feed and veterinary pharmaceutical companies, Universities, Veterinarians, AI industry, Department of Agriculture, Food and the Marine, Irish Cattle Breeding Federation (ICBF).

Practical implications for stakeholders:

The studies conducted for this large-scale multi-disciplinary project have yielded an array of practical outcomes for key stakeholders within the Irish suckler beef industry. These include:

- clear information and management guidelines to ensure early onset of puberty in replacement beef heifers thus supporting the key industry objective of calving such heifers at two years of age.
- a comprehensive biochemical insight into how nutrition during rearing affects sexual development in the young heifer, which in turn will provide the basis of development of genetic biomarkers for the trait.
- a robust and effective timed AI protocol validated using 2200 cows in 80 suckler herds across the island of Ireland. This is now the industry standard regimen and facilitates the use of AI to support the introgression of superior genetics into the national beef cattle.
- a large-scale, comprehensive analaysis of both the disease and trace element status of Irish beef cow herds was undertaken, involving in excess of 6000 beef across 160 herds, located in every county on the island of Ireland. Clear industry statistics have been generated as well information on the likely impact of disease and mineral status on herd productive performance. Insight into farmer opinions on a range of reproductive technologies and practices was also garnered through a large-scale survey.
- development of a unique and dynamic bioeconomic model, to assess the likely impact of various reproductive management strategies on farm profit.

Main results:

1. Improving the plane of nutrition during the first 4 to 8 months of life has a much greater influence on the rate of sexual development and subsequent age at onset of puberty than nutritional management thereafter. Our results provide unique evidence that this process is mediated by differential expression of key microRNA, messenger RNA transcripts and proteins across an array of metabolic, brain and reproductive tissues.
2. Strategic usage of a progesterone based timed artificial insemination program can result in very acceptable conception rates in beef suckler cows when implemented during the period immediately following uterine involution (35 days after calving). This facilitates a high proportion (ca. 80%) of the herd to be successfully bred and become pregnant within the first three weeks of the breeding season, thus dramatically reducing average herd calving interval and increasing the number of calves sired by genetically elite sires.
3. The largest and most comprehensive survey of the sero-status of the national beef cow herd for the four main reproductive pathogens was conducted for the island of Ireland. In addition, status for key trace elements viz. copper, selenium and iodine was established. There was no appreciable evidence for a relationship between either sero-status for reproductive pathogen exposure or indeed the trace elements, copper, selenium and iodine and poor reproductive or productive performance of suckler beef cow herds.
4. Results of a meta-analysis of published studies clearly show that implementing an adequate level of nutrition pre- and to a lesser extent, post-calving can shorten the post-partum interval and calving spread in beef cow herds and also lowered herd barrenness rate. This can be augmented further when short-term suckling restriction of the young calf was implemented and/or cows are exposed to biostimulation from a

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male, prior to the onset of the breeding season. Results from a whole system bioeconomic modelling analysis illustrate that improved reproductive management practices while increasing costs of production, will improve farm profitability.

Opportunity / Benefit: This large scale, multi-disciplinary and multi-institutional, all island project, has resulted in many novel findings as well as clear and implementable recommendations for the Irish suckler beef cattle sector. Readers are also directed to the many technical articles which have emanated from this project.

Collaborating Institutions:
University College Dublin (UCD)
Agri-Food and Biosciences Institute of Northern Ireland (AFBINI)
Irish Cattle Breeding Federation (ICBF)
Irish Farmers Journal (IFJ)
Department of Agriculture, Food and the Marine, Central Veterinary Laboratory Service (DAFM)
CEVA Animal Health

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1. **Project background:** The lifetime productivity of the beef bred female commences from the onset of puberty and is dictated by subsequent critical events including age at first calving, duration of the postpartum interval for each successive calving, conception and pregnancy rate and ultimately manifested as length of inter-calving interval and number of calves weaned over her lifetime.
   The productive life of the beef bred female commences at first calving. Breeding heifers to calve at 24 months of age, a key target for suckler herds, requires the majority to undergo puberty at least 42 days prior to the start of breeding. While it is known that the trajectory of sexual development in the heifer is influenced by genetics but mainly by nutritional status, at the outset of this project there was little information in Ireland to support optimum rearing management strategies to ensure early onset of puberty for the predominant replacement heifer genotypes. Additionally, given the logistical difficulty of recording age at puberty onset at farm level and lack of adequate phenotypes, the availability of robust molecular markers to aid genomic selection are desirable to support on-going progress for the trait.
   Despite the potential for high conception rates only one of every four to five calves born to suckler cows in Ireland is bred by AI. Difficulties associated with heat detection, have led to increased international interest in the development of effective oestrous synchronisation protocols for beef cows. While apparently effective regimens (i.e. GnRH-progesterone-prostaglandin based) which facilitate the use of timed AI (TAI) for beef cows have been developed in some countries, prior to the commencement of the BEEFCOW project, these had not been evaluated within the context of seasonal calving beef cow herds.
   The potential contribution of various infectious diseases towards reproductive wastage has received much international attention in recent decades, particularly for dairy herds. However, despite their acknowledged prevalence in many Irish beef herds was little or no quantitative information, heretofore, on either sero-status of the national herd for the main contributory pathogens or indeed their relative contribution to cow reproductive performance in Ireland. Both issues were addressed for the current project. Bioeconomic models have been shown to be very useful tools to aid farm management decisions. The development of a robust bio-economic simulation model was necessary to aid accurate reproductive management decisions for beef herds and assist producers, advisors and veterinarians select the optimum suite of reproductive technologies, or to assess the economic consequences of alternative management/system scenarios.
2. **Questions addressed by the project:** The main objectives of this proposed project were: (i) develop strategies to reduce the age of onset of puberty and first calving of beef heifers and understand some of the underlying molecular mechanisms controlling the trait; (ii) develop a robust protocol to facilitate the

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use of timed artificial insemination for beef cows; (iii) Quantify the influence, if any, of exposure to key pathogenic micro-organisms as well as trace element status on cow reproductive efficiency on Irish suckler cow herds; (v) develop a robust bioeconomic model to assist cost efficient reproductive management of beef cows as well as informing the national genetic evaluation programme; (vi) implement a coherent strategy for the dissemination of clear advice and guidelines to facilitate best practice in the reproductive management of spring calving suckler cows

3. The experimental studies:

Heifer puberty: A series of studies were designed to 1) determine age at puberty for heifers of different genotypes; 2) establish genotype-specific growth rates and target bodyweights to ensure puberty and early conception; 3) identify appropriate nutritional regimes during the pre-pubertal period to achieve these targets; 4) gain a comprehensive insight into the physiological and molecular regulation of sexual development of the heifer from early calfhood to puberty onset. The studies employed over 450 heifers, born to either dairy or suckler beef cows and sired by bulls of either late or early maturing breeds. Studies involve an examination of the effect of high compared to a moderate planes of nutrition during (i) early calfhood,; (ii) 4-9 months of age or (iii) from 8 months of age to puberty onset. For the studies (ii) and (iii), age at puberty was determined as was post pubertal fertility, while a very comprehensive and novel endocrinological and molecular characterisation of the effect of plane of nutrition during early calfhood on an array of key metabolic, brain and reproductive tissues was conducted.

Timed artificial insemination: A total of 2206 suckled cows located on 74 herds throughout the island of Ireland were enrolled on the study, which was replicated in spring and autumn. Cows calved a minimum of 35 days were assigned to receive a 7 day progesterone-releasing intravaginal device (PRID) either with or without administration of gonadotropin releasing hormone (GnRH) analogue at PRID insertion and all received prostaglandin F2α was given at PRID removal. A third group of cows also received 400 IU equine chorionic gonadotropin (eCG) at PRID removal. GnRH was administered at TAI 72 h after PRID removal. Pregnancy diagnosis was conducted 35-40 days after TAI.

All island epidemiology study of reproductive pathogen and trace element status of Irish suckler beef herds: Over 6000 cows from in excess of 160 spring calving beef cow herds across the Republic of Ireland and Northern Ireland were blood sampled to measure the sero-prevalence of Leptospirosis (hardjo-bovis and -prajitno genotypes), bovine viral-diarrhoea virus (BVDV), bovine herpesvirus-1 (BHV-1; causative agent for Infectious Bovine Rhinotracheitis) and Neospora caninum as well as the trace elements, copper, selenium and iodine. Data for calving interval, calf mortality and estimated calf average daily gain were extracted from the Irish Cattle Breeding Federation database. The relationship between sero-status for the aforementioned pathogens/trace elements and various herd productive and reproductive traits was established.

Bioeconomic modeling of reproductive management

The objective of this work was to investigate the factors which affect the duration of the reproductive cycle in suckled beef cows, and further, to evaluate how these factors can be affected by alternative reproductive management strategies using a *de novo* dynamic model framework. Management scenarios investigating differences in nutrition, maternal offspring bonding, biostimulation and parity were simulated on whole herd performance. Outcomes from these reproductive management scenarios were evaluated in terms of whole farm technical and economic performance. The potential effect of herd BHV-1 status on the technical and economic performance of a pasture based SB herd using the aforementioned national serological dataset was modeled.

4. Main results:

Heifer puberty: Heifers offered a high (HI) compared to moderate (MOD) plane of nutrition overwinter diet from approx. 8 months of age were 13 days younger and 29 kg heavier at puberty. Six-week submission rate was greater for HI compared to MOD heifers; however, there was no difference in 6- or 12- week pregnancy rate. Compared with beef-bred heifers, dairy-bred heifers were of similar age (429 vs. 432 days) but 56 kg lighter at puberty. Both 6- and 12-week pregnancy rate were greater for dairy- compared with beef-bred heifers. Early-maturing heifers were 15 days younger and 18 kg lighter at puberty than LM heifers. Six-week submission rate did not differ between EM and LM heifers; however, 6-week pregnancy rate was greater for EM than LM heifers whereas, there was no difference in 12-week pregnancy rate. In a second study, Angus cross heifers were offered either a HI or MOD plane of nutrition at pasture between four and nine months of age. A greater percentage of HI heifers were pubertal at 300 (2 vs. 32%), 350 2 vs 41%), 400 (4 vs. 44% and 450 (46 vs. 87%) days of age compared to MOD heifers. However, there was no difference in pubertal status or pregnancy rate (73 vs. 77%) between the feeding treatments when bred at 500 days of age. In a third study Angus cross heifer calves were offered a HI or MOD diet from three to 21 weeks of age resulting in respective growth rates of 1.18 and 0.50 kg/day. Reponses in terms of blood concentrations of key metabolic and reproductive hormones as well as the transcriptome and proteome of veracious key metabolic, brain and reproductive

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tissues would suggest a general advancement of sexual development of the calves offered the high plane of nutrition.

Timed AI: Mean BCS was 2.75 and 2.92 for S and A cows respectively and was not different between treatments. Overall BCS was positively associated with pregnancy rate. Cows that had resumed ovarian cyclicity at treatment initiation had increased pregnancy rate. Overall mean pregnancy rate was 54% across season and treatments. The administration of GnRH at the initiation of a 7 day Co-Synch+PRID protocol as well as supplementation of 400 IU of eCG at PRID removal, both increased pregnancy rate in spring but not autumn calving cows. When combined with subsequent repeat breeding using either natural service or AI our studies show that up to 80% of the original treated cows became pregnant during the first three weeks of the breeding season, which could have a major impact on shortening the calving internal both at an individual farm and at a national level.

Epidemiology study of reproductive pathogens and trace elements: The average number of cows tested per herd was 35.5 (median 30). Mean BCS ± s.e.m was 2.57 ± 0.01 for all cows sampled. Herd level seroprevalence BHV-1, BVDV, Leptospirosis and Neosporosis was 90%, 100%, 91% and 67%, respectively, while the mean within herd prevalence for the these pathogens was 40%, 77.7%, 65.7% and 5.7%, respectively. Sero-prevalence of leptospirosis, BVDV and BHV-1 was 88%, 92% and 33% and 71%, 78% and 44% in vaccinating and non-vaccinating herds, respectively. The study confirmed that the level of seroconversion for the four pathogens of interest increases with herd size. There was also evidence that exposure to one pathogen may increase the risk of exposure to another pathogen. While variable between herd and region, systemic concentrations of copper, iodine and selenium indicated that 15, 82 and 79 percent of all cows sampled were below the minimum recommended threshold at the time of sample. Overall herd pregnancy rate across the two years of the study was 89% (78-100%). There was no appreciable effect of sero-positivity status for any pathogen or trace element measured on calving interval, calf mortality (≤28 days) or calf average daily gain.

Bioeconomic modelling

Results from the meta-analysis indicated that length of the postpartum interval beef cows is primarily affected by body condition score at calving and maternal offspring bond in addition postpartum plane of nutrition and parity. A dynamic deterministic model was developed to simulate the reproductive cycle of a suckled beef cow herd, with specific emphasis on the postpartum anoestrus interval (PPAI). Results indicated that maintaining a high level of nutrition pre- and post-calving, truncated the calving distribution towards the beginning of the breeding season and lowered herd cull rates due to barrenness. This effect was increased further when farmers restricted access of the new-born calf to her dam and/or exposed cows to biostimulation from a male, prebreeding. The effect of these factors on farm profitability was also quantified. A minor reduction in net margin was initially found in herds as a result of seropositivity for BHV-1 (4%), with herds larger in size and without an active vaccination policy, observing further reductions in economic performance.

5. **Opportunity/Benefit:** This all-island, comprehensive and multifaceted large scale research program examined many important issues that contribute to the reproductive and, as a consequence, economic performance of beef cow herds in Ireland. We have developed clear information and recommendations for the nutritional management of replacement heifers, timed AI as well as quantifying the impact of various animal health factors and management strategies on herd profitability. Results and outcomes from the work conducted for this project have been widely disseminated at national and international scientific and technical conferences and industry fora as well as in the national popular agrifood industry press.

6. **Dissemination:** A large number of scientific and technical articles as well as three PhD theses have been disseminated from this project. Three representative examples are included below.

I. Heslin JA, Kenny DA, Kelly AK, Crowe MA and McGee M. (2020). Age at puberty and pregnancy rate in beef heifer genotypes offered contrasting nutrition levels from 8 to 13 months of age. Animal Reproduction Science (In Press).

II. Barrett D., Parr M.H., Fagan J., Johnson A., Tratalos J., Lively F., Diskin M.G. & D.A Kenny. 2018. Prevalence of Bovine Viral Diarrhoea Virus (BVDV), Bovine Herpes Virus 1 (BHV 1), Leptospirosis and Neosporosis, and associated risk factors in 161 Irish beef herds. BMC Veterinary Research 14: 8-18

III. Lynch R, Kenny DA, Parr MP, Kelly AK and Crosson P. 2018. Modelling the impact of Bovine Herpesvirus-1 seropositivity on the technical and economic performance of a pastoral based suckler beef system. The Journal of Agricultural Science 156: 557–564.

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