GENETIC IMPROVEMENT OF PASTURE INTAKE AND EFFICIENCY IN BEEF CATTLE: ARE WE THERE YET?

P.F. Arthur[1], R.M. Herd[2], P.L. Greenwood[2], K.A. Donoghue[3] and T. Bird-Gardiner[3]

[1]NSW Department of Primary Industries, Elizabeth Macarthur Agricultural Institute, Menangle, NSW, 2568
[2]NSW Department of Primary Industries, Livestock Industries Centre, Armidale, NSW, 2351
[3]NSW Department of Primary Industries, Agricultural Research Centre, Trangie, NSW, 2823

SUMMARY

Currently feed intake can be accurately and easily measured in cattle that are lot-fed prepared feeds, commonly using automatic feed intake recorders, and the data from these underpin the BREEDPLAN® feed efficiency trait, Net Feed Intake. However, a large proportion of beef production in most countries including Australia and New Zealand is either fully or partially pasture-based. There are now emerging technologies which have capability for automation, have reasonable level of accuracy in estimation of feed intake, and the ability to be deployed on pastures. With further development a pasture intake and efficiency trait can be a reality.

INTRODUCTION

Profitability of beef production depends on both inputs and outputs. Providing feed to cattle is the single largest input cost in most commercial beef production enterprises, and thus improving the efficiency of feed use will help reduce input costs. In beef cattle, genetic improvement of feed use is currently possible in Australia through the use of the BREEDPLAN® trait, Net Feed Intake (NFI), which is also known in the scientific literature as residual feed intake (Berry and Crowley 2013). An important factor in the development of any feed efficiency trait is an ability to accurately measure feed intake of each animal. Currently feed intake can be accurately and easily measured in cattle that are lot-fed prepared feeds, commonly using automatic feed intake recorders. However, a large proportion of beef production in most countries including Australia is either fully or partially pasture-based; as illustrated by Australian commercial labels – "grassfed beef" and "grainfed beef"; the latter referring to cattle raised on pasture and finished on grain-based diet in feedlots, and the national breeding cow herd is pasture-based. There is currently no individual animal feed efficiency measure for pasture-based cattle, mainly due to the challenge of measuring individual animal pasture intake accurately and easily. The objective of paper is to review currently available methods of measuring individual animal pasture intake and provide some of the relevant results to date with a view to stimulating interest in progressing development of strategies for a pasture intake and/or efficiency trait for genetic improvement in beef cattle.

PASTURE INTAKE MEASUREMENT TECHNOLOGIES

Unlike prepared rations, pasture intake by cattle is difficult to measure directly. There are currently a number of technologies available for estimating pasture intake by cattle and their suitability for use would depend, among other considerations on accuracy, cost and ease of use and potential for automation. These measurement technologies include:

Marker technologies. *Chromium oxide, other metallic oxides and non-metallic markers.* These markers have been used for many decades to estimate faecal output by grazing animals, and with knowledge of the composition and digestibility of the diet consumed, an estimate of pasture intake can be calculated (Mayes and Dove 2000). The technique requires daily dosing of animals with the marker, which can interrupt animal's normal grazing behaviour, or administration of a bolus of marker in an intra-ruminal controlled release devise (CRD) which releases a controlled dose of marker into the rumen over days and weeks, obviating the need for daily dosing. Both methods require animals to be mustered regularly, typically twice weekly, for collection of a faecal sample which must then be subsequently analysed for its' concentration of chemical marker. Concern over residues of metallic oxide makers in animals and the environment and non-registration of these markers for use in livestock currently limit their repeated use in individual animals and large numbers of animals.

n-alkanes and other plant chemical constituents. These have been proposed as alternative markers to metallic oxides and also offer the capacity to estimate the proportions of some pasture species and supplements consumed by grazing animals, as well as estimation of faecal output and feed intake (Mayes and Dove 2000).

Use of both groups of markers share the same limitations, being the need for dosing of animals, frequent mustering for collection of faecal samples, sampling of pasture species and supplements on offer, sample storage and preparation (typically, freezing, drying and grinding) and laboratory chemical analysis. Only the last step offers scope for automation. Experiments using markers to estimate faecal output and feed intake have typically been conducted over much shorter time periods (rarely more than 3 weeks) then recommended for cattle undergoing a feed efficiency test on complete mixed rations. Despite these limitations, markers have been used in Australia to estimate pasture intake by relatively large numbers of grazing beef cattle (Barlow *et al*. 1990; Dicker *et al*. 1998; Herd *et al*. 2004), and by sufficiently large numbers of sheep to estimate phenotypic and genetic parameters (Lee *et al*. 1995; Lee *et al*. 2002; Fogarty *et al*. 2006)

Wireless sensor technologies. Use of wireless sensors in estimating pasture intake has advantages including provision of an array of sensor-based data including locations, behaviours such as grazing and ruminating, and specific applications such as pasture intake over longer time periods in the commercial grazing environment, and in a timely manner, potentially in real-time, without the high labour inputs and need for repeated handling of cattle of other methods. They also have potential for commercial applications in addition to research. Development of simple initial algorithms from sensor data to classify behaviours that predicted 60% of measured variation in pasture intake by individual beef cattle has been achieved under experimental conditions (Greenwood *et al*. 2017). A range of sensor types including movement-based sensors such as accelerometers, magnetometers and gyroscopes within inertial measurement units, and acoustic and pressure sensors, attached to various on-animal locations using devices such as collars, ear tags, halters, nose-bands and leg straps have been used in studies aimed at extracting features that enable classification of cattle behaviours and other measurements from which estimates of intake may be made in intensive and extensive situations (Greenwood *et al*. 2014; Andriamandroso *et al*. 2016). Further research and developments are required to enable validation and refinement of algorithms, including more specific classification of pasture consumption events within grazing systems using sensors, development of new algorithms that include other sources of variation within and between grazed and browsed forages that impact on intake and selectivity, development of more commercially useful sensor devices, and deployment of sensor devices on large numbers of livestock in commercial grazing environments. In achieving these outcomes, issues that need to be considered include software development required for the collection of data from multiple types of sensors, the management and analyses of the very large volumes of data, determination of which sensing modalities are sufficient and/or necessary, management of the constrained power source, and generation of high-quality benchmark pasture intake and other data from which sensor data features, and behaviour classification and pasture intake algorithms can be established (Greenwood *et al*. 2014, 2017).

Emissions measurement technologies. Heat production (HP) is commonly used to assess the energy expenditure of an animal. This is based on the close relationship between HP and the process of oxidation of organic matter (feed) where oxygen (O_2) is consumed, and carbon dioxide (CO_2) and methane (CH_4) emitted (Blaxter 1962). Dry energy intake (DMI) can then be calculated by HP and a measure of the energy retained by the animal. The main challenge is accurately measuring the gases in the animal's production setting, and procedures used in the past include trachea fistulation (e.g. Flatt *et al*. 1958), isotope dilution technique (e.g. Whitelaw *et al*. 1972) and respiration pattern analysers (Young *et al*. 1975). The main drawbacks of these techniques are they cannot be used in the animal's production setting and that only a small number of animals can be measured at a time.

Sulphur hexafluoride (SF_6) tracer-gas technique. SF_6 can be used in the animal's production environment and has the potential of being used to measure a reasonable number of animals at a time. It has a minimal capacity for automation. It should be noted that while most studies have reported good accuracy for CH_4 measurement by SF_6, some studies have reported overestimation of individual animal CO_2 results, although animal rankings are maintained relative to respiration chamber measurements (Boadi *et al*. 2002; Pinares-Patiño *et al*. 2007).

Respiration chambers. These have the highest accuracy of measurement and can be used to measure large numbers of animals but cannot be used in the animal's production environment. Animals in respiration chambers usually consume less feed than they would in their normal production setting (Bickell *et al*. 2014; Herd *et al*. 2016).

In a beef cattle study, CH_4 and CO_2 production from 1,096 roughage fed beef cattle was measured in respiration chambers. Phenotypic and genetic correlations between DMI and CH_4 were 0.71 and 0.84, respectively (Donoghue *et al*. 2016). Similarly high correlations were obtained between DMI and CO_2 for the same cattle (Bird-Gardiner *et al*. 2018). While these results are promising, it should be noted that in the respiration chambers the cattle were fed 1.2 times their estimated maintenance requirements, which is lower than their expected *ad libitum* intake. These results therefore needed to be confirmed in cattle fed *ad libitum* in their production environment.

Short-term Breath Monitors. There are currently available equipment that use multiple short-term breath measurements, such as the GreenFeed Emission Monitors (GEM; C-Lock Inc., Rapid City, SD, USA). The GEM offers a good degree of automation, can be used in the animal's production environment, and can be used to measure large numbers of animals. This technology is new relative to the others and test procedures to improve the estimation of emissions are being optimised (e.g. Arthur *et al*. 2017).

In a study involving 119 heifers (in yards at Trangie) fed roughage diet *ad libitum* and 326 steers (in a feedlot near Armidale) fed feedlot diet *ad libitum* using GEM, Bird-Gardiner *et al*. 2017 reported a phenotypic correlation between DMI and CH_4 of 0.75 for the heifers and 0.62 for the steers. Phenotypic correlations between DMI and CO_2 of 0.84 for the heifers and 0.83 for the steers were reported by Arthur *et al*. (2018). Similar results were obtained in a Canadian study with heifers (Manafiazar *et al*. 2017). These results are encouraging given that of all the emissions measurement technologies, the GEM is easiest to deploy on pasture, and have been used in some pasture studies (Velasco *et al*. 2017; Gunter and Beck 2018) for purposes other than predicting pasture intake.

GENERAL CONSIDERATIONS

Irrespective of the technology used to estimate pasture intake, it will be necessary for samples of pastures consumed by animals to be taken at strategic times for analyses of potential digestibility and metabolisable energy (ME) content, to enable estimates of faecal output or energy metabolism to be converted to units of intake. Secondly, animal measurements such as liveweight, weight gain and fat scans taken while the animals are on pasture is necessary to relate intake to efficiency, and advances in automated liveweight recording will be very useful. While it may be logical to use several individual traits (e.g. CO_2 and CH_4) to produce an estimate of pasture intake, there is the possibility that using one or more of the traits directly may be a more efficient and cost-effective approach. An example may be a scenario where the genetic correlation between CO_2 and ME intake of cattle fed *ad libitum* in their production setting is greater than 0.85.

In conclusion, there is a need to capture pasture intake and efficiency in our beef genetic improvement system, given that most of the beef production systems in Australia and New Zealand are pasture based. There are emerging technologies which have capability for automation with reasonable levels of accuracy, and the ability to be deployed at pasture.

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