# An evaluation of the accuracy and precision of methane prediction equations for beef cattle fed high-forage and high-grain diets

P. Escobar-Bahamondes 1, 2, 3, M. Oba 2, and K. A. Beauchemin 1

1 *Agriculture and Agri-Food Canada (AAFC), 5403 1st Ave. S. PO Box 3000, Lethbridge, AB. T1J 4B1, Canada*

2 *Dept. of Agricultural, Food & Nutritional Science, 4-10J Agriculture/Forestry Ctr University of Alberta, Edmonton, AB. T6G 2P5, Canada*

3 *Instituto de Investigaciones Agropecuarias (INIA) Remehue, Osorno, Región de Los Lagos 5290000, Chile*

**Supplementary Table S1.** Summary of studies included in the complete database.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Author(s) | Animal category | Breed | CH4 measurement method | CH41 (g/d) | Treatment description |
| Beauchemin and McGinn (2005) | Steers | Angus | Chambers | 62.1 | Barley and corn grain in different proportions |
| Beauchemin and McGinn (2006a) | Heifers | Angus | Chambers | 141.5 | Forage and grain in different proportions and unrestricted and restricted intake levels |
| Beauchemin and McGinn (2006b) | Steers | Angus | Chambers | 108.0 | Lipids, fumaric acid, spice extract, high proportion of forage and high proportion of grain under restricted feeding |
| Beauchemin *et al.* (2007a) | Steers | Angus | Chambers | 119.6 | Different sources of lipids |
| Beauchemin *et al*. (2007b) | Steers / heifers | Angus | Chambers | 98.7 | Different concentration of Quebracho tannins |
| Boadi and Wittenberg (2002) | Heifers | Holstein and Charolais × Simmental | SF6 | 127.6 | Different qualities of diets assessed as IVOMD |
| Boadi *et al*. (2001) | Steers | Red Angus | SF6 | 169.1 | Different proportions of alfalfa, bromegrass pastures with barley |
| Boadi *et al.* (2004) | Steers | Continental × British crossbred | SF6 | 59.4 | Different proportions of forage and grain |
| Boland *et al*. (2013) | Heifers | Limousin | SF6 | 127.0 | Availability of herbage mass |
| Chaves *et al.* (2006) | Heifers | Angus | SF6 | 150.9 | Grazing different types of alfalfa or grass pasture |
| Chung *et al.* (2013) | Heifers | Crossbred | Chambers | 90.0 | Proportions of alfalfa and sainfoin at different stages of maturity |
| Chung *et al*. (2011) | Steers | Holstein | SF6 | 261.0 | Different yeast strains (*Sacharomyces cerevisiae*) |
| Chung *et al*. (2013) | Heifers | Crossbred | Chambers | 90.0 | Proportions of alfalfa and sainfoin at different stages of maturity |
| Cooprider *et al*. (2011) | Steers | Angus cross steers | Chambers | 281.8 | Conventional management (estrogen+monensin+others) vs management without antibiotics, estrogenic hormones and others |
| Doreau *et al*. (2011) | Bulls | Blond d'Aquitaine | SF6 | 62.3 | Different diets of corn grain, grass hay and corn silage |
| Dos Santos Pedreira *et al*. (2012) | Steers | 3/4 Holstein × Zebu | SF6 | 113.0 | Cultivars of sugarcane plus urea |
| Fiorentini *et al*. (2014) | Steers | Nellore | SF6 | 91.7 | Lipid sources with different fatty acid profiles |
| Fitzsimons *et al*. (2013) | Heifers | Simmental | SF6 | 260.0 | Different residual feed intakes using 100 grass silage |
| Grainger *et al*. (2008) | Steers | Holstein | SF6 | 399.0 | Supplementation with whole cottonseed |
| Gutierrez *et al*. (2007) | Steers | Holstein | SF6 | 113.8 | Concentrations of nitroethane plus dry rolled corn |
| Hales *et al*. (2012) | Steers | Jersey | Chambers | 38.8 | Different corn processing methods plus inclusion of WDGS |
| Hales *et al*. (2013) | Steers | Jersey | Chambers | 46.1 | Increments of WDGS in steam flaked corn based diets |
| Hales *et al*. (2014a) | Steers | Cross | Portable head boxes | 93.3 | Levels of dietary roughage using dry rolled corn and WDGS diets |
| Hales *et al*. (2014b) | Steers | MARC 1 | Portable head boxes | 107.5 | Levels of glycerin on energy metabolism, nutrient balance and eCH4 |
| Hart *et al*. (2009) | Heifers | Charolais cross | SF6 | 138.0 | Levels of sward dry matter digestibility |
| Henry *et al*. (2015) | Heifers | Crossbreed | SF6 | 87.5 | Effects of chitosan on nutrient digestibility |
| Hegarty *et al*. (2007) | Steers | Angus | SF6 | 142.3 | Greater and lower residual feed intake |
| Hosoda *et al*. (2012) | Steers | Holstein | Chambers | 99.9 | Levels of soy sauce cake |
| Hulshof *et al*. (2012) | Steers | Nellore × Guzera | SF6 | 85.0 | Effects of nitrate supplementation of sugarcane based diets |
| Hunerberg *et al*. (2013a,b) | Heifers | Crossbred | Chambers | 119.0 | Effects of DDGS using finishing and growing beef cattle diets |
| Jiao *et al*. (2013) | Heifers | Holstein | Chambers | 96.4 | Efficiency of energy using UK diets |
| Jones *et al*. (2011) | Steers | Angus | FTIR | 125.1 | High and low residual feed intake with low and high quality of pasture |
| Jordan *et al*. (2006a) | Steers | Charolais - Limousin cross | SF6 | 55.4 | Effects of refined soy oil and whole soybeans |
| Jordan *et al*. (2006b) | Heifers | Charolais - Limousin cross | SF6 | 55.4 | Effects of refined coconut oil or copra meal |
| Lee *et al*. (2015) | Heifers | Crossbred | Chambers | 183.0 | Effect of source of nitrate |
| Li *et al*. (2012) | Steers | Holstein | Chambers | 82.4 | Sources of saponins |
| Lila *et al*. (2005) | Steers | Holstein | Chambers | 77.0 | Effects of sarsaponin on ruminal fermentation |
| Lovett *et al*. (2003) | Heifers | Charolais cross | SF6 | 112.2 | Different ratios of forage and grain with or without coconut oil |
| Mc Geough *et al*. (2010a) | Steers | Continental crossbred | SF6 | 180.0 | Different ratios of wheat grain and straw/chaff |
| Mc Geough *et al*. (2010 b) | Steers | Crossbred | SF6 | 228.0 | Stages of silage corn maturity |
| McGinn et al. (2004) | Steers | Holstein | Chambers | 129.0 | Monensin, sunflower oil, enzymes, yeast and fumaric acid |
| McGinn *et al*. (2009) | Steers | Hereford | SF6 | 177.0 | Effects of DDGS |
| Molano *et al*. (2006) | Steers | Hereford × friesian | SF6 | 89.1 | Effects of New Zealand hill pasture in different seasons |
| Newbold *et al*. (2014) | Steers | Holstein | Chambers | 86.8 | Effects of dietary nitrate levels |
| Pinares-Patiño *et al*. (2003) | Steers | Charolais | SF6 | 204.4 | Physiological stages of Timothy grass |
| Romero-Pérez *et al*. (2014) | Heifers | Angus | Chambers | 203. | Use of 3-nitrooxypropanol |
| Romero-Pérez *et al*. (2015) | Heifers | Angus | Chambers | 157.9 | Long term use of 3-nitrooxypropanol |
| Stackhouse *et al*. (2011) | Steers | Angus | Chambers | 68.4 | Emissions from Holstein Angus-cross feedlot steers during representative growth stages |
| Stackhouse *et al*. (2013) | Steers | Angus | Chambers | 239.0 | Effects of growth promoting technologies on animal performance and emission rates |
| Staerfl *et al*. (2012) | Steers | Brown Swiss × Limousin | Chambers | 37.4 | Long term evaluation of feeding acacia tannin, garlic, maca and lupine to bulls fattened on grass or corn silage |
| Troy *et al*. (2015) | Steers | Charolais and Luing | Chambers | 194.3 | Effects of nitrate addition and oil |
| Vyas *et al*. (2014a) | Heifers | Crossbred | Chambers | 177.5 | *Propionibacterium* strains using high forage diets |
| Vyas *et al*. (2014b) | Heifers | Crossbred | Chambers | 138.5 | *Propionibacterium* strains using corn grain based diets |
| Vyas *et al*. (2015) | Heifers | Crossbred | Chambers | 187.8 | Effects on vivo of *Propionibacterium* strains |
| Vyas *et al*. (unpublished) | Steers | Crossbred | Chambers | 125.9 | Use of 3-nitrooxypropanol for backgrounding and finishing cattle |

1Average for each study.

DDGS, dried distillers grains plus solubles; FTIR, Fourier transform infrared spectroscopy; IVOMD, in vitro organic matter digestibility; SF6, sulfur hexafluoride tracer gas technique; WDGS, wet distillers grains with solubles.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Supplementary Table S2.** Methane prediction (MJ/d) equations for beef cattle used in the study   |  |  |  |  | | --- | --- | --- | --- | | N | Original source and equation | Equation | | | 1 | IPCC (2006), Tier 2 | CH4 = | (DMI × 18.5 (MJ/kg DM) × Y*m* ) /55.65 (MJ/kg CH4) | | 2 | Ellis *et al*. (2007), 1b | CH4 = | 4.38 + 0.0586 × MEI | | 3 | Ellis *et al*. (2007), 2b | CH4 = | 3.96 + 0.561 × DMI | | 4 | Ellis *et al*. (2007), 3b | CH4 = | 4.79 + 0.0492 × forage ( ) | | 5 | Ellis *et al*. (2007), 4b | CH4 = | 5.263 + 6.93 × lignin | | 6 | Ellis *et al*. (2007), 5b | CH4 = | 5.58 + 0.848 × NDF | | 7 | Ellis *et al*. (2007), 6b | CH4 = | 5.70 + 1.41 × ADF | | 8 | Ellis *et al*. (2007), 7b | CH4 = | 3.05 + 0.0371 × MEI + 0.801 × NDF | | 9 | Ellis *et al*. (2007), 8b | CH4 = | 3.31 + 0.0382 × MEI + 1.05 × ADF | | 10 | Ellis *et al*. (2007), 9b | CH4 = | 0.357 + 0.0591 × MEI + 0.0500 × forage ( ) | | 11 | Ellis *et al*. (2007), 10b | CH4 = | -1.02 + 0.681 × DMI + 0.0481 × forage ( ) | | 12 | Ellis *et al*. (2007), 11b | CH4 = | 2.30 + 1.12 × DMI - 6.26 × lignin | | 13 | Ellis *et al*. (2007), 12b | CH4 = | 2.7 + 1.16 × DMI - 15.8 × EE | | 14 | Ellis *et al*. (2007), 13b | CH4 = | 0.183 + 0.0433 × MEI + 0.647 × NDF + 0.0372 × forage ( ) | | 15 | Ellis *et al*. (2007), 14b | CH4 = | 2.94 + 0.0585 × MEI + 1.44 × ADF - 4.16 × lignin | | 16 | Ellis *et al*. (2009), A | CH4 = | 2.29 + 0.670 × DMI | | 17 | Ellis *et al*. (2009), B | CH4 = | 3.05 + 3.71 × CEL | | 18 | Ellis *et al*. (2009), C | CH4 = | 4.72 + 1.13 × starch | | 19 | Ellis *et al*. (2009), D | CH4 = | 6.01 + 0.345 × NFC | | 20 | Ellis *et al*. (2009), E | CH4 = | 3.46 + 5.06 × sugar | | 21 | Ellis *et al*. (2009), F | CH4 = | 3.32 - 1.23 × starch + 9.48 × sugar | | 22 | Ellis *et al*. (2009), G | CH4 = | -1.01 + 2.76 × NDF + 0.722 × starch | | 23 | Ellis *et al*. (2009), H | CH4 = | 2.26 + 5.02 × sugar + 0.0236 × forage ( ) | | 24 | Ellis *et al*. (2009), I | CH4 = | 2.72 + 0.0937 × MEI + 4.31 × CEL - 6.49 × HC - 7.44 × fat | | 25 | Ellis *et al*. (2009), J | CH4 = | 0.310 + 2.88 × CEL + 4.15 × CP - 3.97 × fat | | 26 | Ellis *et al*. (2009), K | CH4 = | 0.561 + 5.86 × CEL + 0.526 × NFC | | 27 | Ellis *et al*. (2009), L | CH4 = | 2.61 + 0.0687 × MEI + 5.99 × sugar - 2.15 × starch | | 28 | Ellis *et al*. (2009), M | CH4 = | 2.79 - 1.04 × (NFC:NDF) + 0.798 × DMI | | 29 | Ellis *et al*. (2009), N | CH4 = | 2.68 - 1.14 × (starch:NDF) + 0.786 × DMI | | 30 | Ellis *et al*. (2009), O | CH4 = | 2.58 - 0.339 × (NFC:ADF) + 0.774 × DMI | | 31 | Ellis *et al*. (2009), P | CH4 = | 2.50 - 0.367 × (starch:ADF) + 0.766 × DMI | | 32 | Ellis *et al*. (2009), Q | CH4 = | 7.09 × {1 - exp[-18.9 × fat]} | | 33 | Ellis *et al*. (2009), R | CH4 = | 8.53 × {1 - exp[-0.637 × NDF]} | | 34 | Ellis *et al*. (2009), S | CH4 = | 8.76 × {1 - exp[-1.86 × HC]} | | 35 | Ellis *et al*. (2009), T | CH4 = | 8.51 × {1 - exp[-5.50 × lignin]} | | 36 | Ellis *et al*. (2009), U | CH4 = | 8.23 × {1 - exp[-1.68 × ADF]} | | 37 | Ellis *et al*. (2009), V | CH4 = | 8.48 × {1 - exp[-0.0230 × MEI]} | | 38 | Ellis *et al*. (2009), W | CH4 = | 10.8 × {1 - exp[-0.141 × DMI]} | | 39 | Ellis *et al*. (2009), W1 | CH4 = | 10.8 × (1 - exp{-[-0.0127 × ( NFC: ADF ) + 0.220 ] × DMI}) | | 40 | Ellis *et al*. (2009), W2 | CH4 = | 10.8 × (1 - exp{-[-0.0138 × ( starch:ADF ) + 0.211 ] × DMI}) | | 41 | Ellis *et al*. (2009), W3 | CH4 = | 10.8 × (1 - exp{-[-0.034 × ( NFC: NDF ) + 0.228 ] × DMI }) | | 42 | Yan *et al*. (2009), iib | CH4= | [[32.4 – 305.8 ME/GE + 199.1 DE/GE + 4.4 ME] DMI – 14.9] × 0.66] × 0.0556 | | 43 | Yan *et al*. (2009), iiib | CH4= | [[1.749 – 12.18 ME/GE + 10.74 DE/GE] GEI – 14.0] × 0.66] × 0.0556 | | 44 | Ricci *et al*. (2013), GEI | CH4 = | 74.34 + 0.57 × GEI - 10.61 × feed - 69.67 × stage - 0.22 × GEI × feed + 0.57 × GEI × stage | | 45 | Ricci *et al*. (2013), DMI | CH4 = | 9.87 + 9.95 × DMI - 15.15 × feed - 74.48 × stage - 3.67 × DMI × feed + 10.90 × DMI × stage | | 46 | Moraes *et al*. (2014), H-GEL | CH4 = | 1.289 + 0.051 × GEI | | 47 | Moraes *et al*. (2014), H-DL | CH4 = | -0.163 + 0.051 × GEI + 0.038 × NDF ( ) | | 48 | Moraes *et al*. (2014), H-AL | CH4 = | -1.487 + 0.046 × GEI + 0.032 × NDF ( ) + 0.006 × BW | | 49 | Moraes *et al*. (2014), S-GEL | CH4 = | 0.743 + 0.054 × GEI | | 50 | Moraes *et al*. (2014), S-DL | CH4 = | 0.743 + 0.054 × GEI | | 51 | Moraes *et al*. (2014), S-AL | CH4 = | -0.221 + 0.048 × GEI + 0.005 × BW |   ADF, acid detergent fiber (kg/d); AL, animal level; BW, body weight (kg); CEL, cellulose (kg/d); CP, crude protein (kg/d); DE, digestible energy (MJ/kg DM); DL, dietary level; DMI, dry matter intake (kg/d); GE, gross energy (MJ/kg DM); GEI, gross energy intake (MJ/d); GEL, gross energy level; H, heifers; HC, hemicellulose (kg/d); ME, metabolizable energy (MJ/kg DM); MEI, metabolizable energy intake (MJ/d); NDF, neutral detergent fiber (kg/d); NFC, non-fiber carbohydrate (kg/d); NSC, non-structural carbohydrates (kg/d); S, steers; stage, physiological stage (nonlactating or lactating); Y*m*, Methane conversion factor (6.5 for diets greater than 90 g forage/kg DM, 3 for diets equal to or less than 90 g forage/kgDM). |

**Supplementary Table S3.** Methane prediction (MJ/d) equations for beef cattle ordered according combined index for high forage dataset.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Equation | R2 adjusted | r*c* | C*b* | RMSPE (g/d) | ECT  % | ER  % | ED  % | MEF | CD | CI | Ranking |
| IPCC 2006 | 0.577 | 0.715 | 0.95 | 39.81 | 1.23 | 0.03 | 98.74 | 0.56 | 1.81 | 24 | 1 |
| Moraes *et al*. (2014) S-AL | 0.632 | 0.725 | 0.90 | 42.85 | 8.90 | 3.93 | 87.17 | 0.59 | 2.17 | 39 | 2 |
| Moraes *et al.* (2014) S-SIM AL | 0.572 | 0.646 | 0.87 | 45.87 | 1.77 | 3.14 | 94.54 | 0.52 | 2.53 | 44 | 3 |
| Moraes *et al*. (2014) S-GEL | 0.425 | 0.678 | 0.86 | 45.76 | 12.80 | 5.44 | 81.76 | 0.53 | 2.45 | 53 | 4 |
| Ellis *et al.* (2009) - N | 0.589 | 0.601 | 0.77 | 35.58 | 9.31 | 14.30 | 76.38 | 0.47 | 3.31 | 56 | 5 |
| Moraes *et al.* (2014) S-DL | 0.617 | 0.678 | 0.86 | 45.76 | 12.80 | 5.44 | 81.76 | 0.53 | 2.45 | 57 | 6 |
| Moraes *et al.* (2014) H-AL | 0.585 | 0.568 | 0.84 | 30.60 | 14.87 | 0.50 | 84.63 | 0.36 | 2.08 | 60 | 7 |
| Moraes *et al*. (2014) H-SIM DL | 0.522 | 0.643 | 0.84 | 29.30 | 27.79 | 0.91 | 71.30 | 0.41 | 1.56 | 61 | 8 |
| Moraes *et al.* (2014) S-SIM GEL | 0.597 | 0.600 | 0.84 | 48.70 | 3.59 | 3.72 | 92.16 | 0.46 | 2.87 | 63 | 9 |
| Yan *et al.* (2009) (iiib) | 0.554 | 0.816 | 0.91 | 37.31 | 46.64 | 1.61 | 52.10 | 0.61 | 0.89 | 63 | 10 |
| Ellis *et al*. (2007) - 14b | 0.513 | 0.568 | 0.81 | 47.00 | 0.34 | 7.07 | 92.60 | 0.45 | 3.86 | 64 | 11 |
| Ellis *et al.* (2009) - P | 0.401 | 0.550 | 0.76 | 37.30 | 6.54 | 10.23 | 83.23 | 0.42 | 3.70 | 65 | 12 |
| Moraes *et al*. (2014) S-SIM DL | 0.521 | 0.600 | 0.84 | 48.70 | 3.59 | 3.72 | 92.16 | 0.46 | 2.87 | 67 | 13 |
| Ellis *et al.* (2009) - M | 0.803 | 0.574 | 0.75 | 37.16 | 14.06 | 12.12 | 73.82 | 0.43 | 3.03 | 70 | 14 |
| Ellis *et al.* (2009) - G | 0.391 | 0.558 | 0.90 | 40.35 | 7.58 | 0.52 | 91.90 | 0.32 | 1.95 | 72 | 15 |
| Ellis *et al.* (2009) - O | 0.588 | 0.533 | 0.76 | 38.38 | 8.36 | 7.01 | 84.63 | 0.39 | 3.41 | 74 | 16 |
| Yan *et al.* (2009) (iib) | 0.522 | 0.783 | 0.90 | 41.72 | 45.84 | 4.44 | 50.06 | 0.51 | 0.80 | 81 | 17 |
| Moraes *et al.* (2014) H-SIM AL | 0.761 | 0.636 | 0.89 | 27.96 | 7.87 | 0.80 | 91.33 | -2.02 | 0.15 | 83 | 18 |
| Ellis *et al.* (2009) - B | 0.472 | 0.453 | 0.82 | 41.98 | 4.52 | 0.01 | 95.47 | 0.27 | 3.04 | 87 | 19 |
| Ellis *et al.* (2007) - 11b | 0.319 | 0.534 | 0.87 | 50.45 | 1.06 | 0.17 | 98.78 | 0.37 | 2.89 | 89 | 20 |
| Moraes *et al.* (2014) H-SIM GEL | 0.756 | 0.639 | 0.80 | 31.12 | 43.96 | 0.56 | 55.48 | 0.34 | 1.20 | 90 | 21 |
| Yan *et al.* (2009) SIM - (iiib) | 0.538 | 0.738 | 0.87 | 44.09 | 49.74 | 0.39 | 50.20 | 0.46 | 0.93 | 90 | 22 |
| Ellis *et al.* (2007) - 1b | 0.643 | 0.523 | 0.71 | 47.61 | 0.05 | 19.00 | 80.96 | 0.44 | 5.85 | 94 | 23 |
| Ellis *et al.* (2007) - 9b | 0.602 | 0.520 | 0.75 | 49.22 | 4.03 | 8.38 | 87.59 | 0.40 | 4.14 | 95 | 24 |
| Ellis *et al*. (2007) - 7b | 0.406 | 0.553 | 0.70 | 47.22 | 7.48 | 22.67 | 69.85 | 0.45 | 4.39 | 97 | 25 |
| Ellis *et al*. (2009) - J | 0.469 | 0.566 | 0.90 | 42.84 | 16.04 | 3.23 | 80.73 | 0.24 | 1.36 | 97 | 26 |
| Moraes *et al*. (2014) H -DL | 0.486 | 0.556 | 0.78 | 33.40 | 35.25 | 0.27 | 64.48 | 0.24 | 1.40 | 101 | 27 |
| Ellis *et al*. (2009) - W1 | 0.746 | 0.370 | 0.57 | 41.01 | 0.51 | 16.98 | 82.51 | 0.30 | 9.97 | 105 | 28 |
| Ellis *et al*. (2007) - 13b | 0.491 | 0.543 | 0.74 | 49.22 | 12.30 | 10.94 | 76.75 | 0.40 | 3.29 | 108 | 29 |
| Yan *et al*. (2009) SIM - (iib) | 0.563 | 0.716 | 0.85 | 46.75 | 53.12 | 0.73 | 46.47 | 0.39 | 0.86 | 109 | 30 |

AL, animal level; DL, dietary level; GE, gross energy (MJ/kg DM); GEI, gross energy intake (MJ/d); GEL, gross energy level; H, heifers; S, steers; SIM, calculated.

**Supplementary Table S4.** Methane prediction (MJ/d) equations for beef cattle ordered according combined index for high grain dataset.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Equation | R2 adjusted | r*c* | C*b* | RMSPE  (g/d) | ECT  % | ER  % | ED  % | MEF | CD | CI | Ranking |
| Ellis *et al*. (2009) - I | 0.163 | 0.445 | 0.84 | 62.87 | 2.32 | 0.16 | 97.52 | 0.26 | 3.00 | 24 | 1 |
| Ricci *et al.* (2013) - GEI | 0.235 | 0.354 | 0.93 | 47.43 | 3.61 | 0.11 | 96.29 | 0.25 | 8.08 | 24 | 2 |
| Moraes *et al.* (2014) S-GEL | 0.294 | 0.406 | 0.71 | 56.35 | 6.02 | 2.67 | 91.31 | 0.27 | 1.68 | 26 | 3 |
| Moraes *et al*. (2014) S-DL | 0.294 | 0.406 | 0.71 | 56.35 | 6.02 | 2.67 | 91.31 | 0.27 | 1.68 | 30 | 4 |
| Moraes *et al.* (2014) S-AL | 0.204 | 0.376 | 0.66 | 57.41 | 7.78 | 3.99 | 88.23 | 0.24 | 5.18 | 37 | 5 |
| Moraes *et al*. (2014) S-SIM GEL | 0.625 | 0.521 | 0.67 | 53.88 | 3.41 | 27.83 | 72.52 | 0.44 | 2.20 | 37 | 6 |
| Ellis *et al*. (2009) - A | 0.216 | 0.278 | 0.56 | 65.21 | 0.72 | 4.15 | 95.13 | 0.20 | 9.74 | 44 | 7 |
| Ellis *et al*. (2007) - 9b | 0.253 | 0.341 | 0.61 | 64.92 | 9.84 | 4.07 | 86.10 | 0.20 | 4.56 | 47 | 8 |
| Moraes *et al*. (2014) S-SIM DL | 0.610 | 0.481 | 0.60 | 55.51 | 3.21 | 32.78 | 61.84 | 0.44 | 2.20 | 48 | 9 |
| Ellis *et al*. (2007) - 8b | 0.185 | 0.253 | 0.51 | 65.08 | 0.59 | 5.95 | 93.46 | 0.19 | 12.34 | 49 | 10 |
| Ellis *et al.* (2007) - 7b | 0.133 | 0.232 | 0.52 | 66.07 | 0.42 | 3.12 | 96.46 | 0.17 | 11.97 | 53 | 11 |
| Ellis *et al.* (2009) - C | 0.251 | 0.351 | 0.67 | 66.46 | 11.26 | 1.28 | 87.46 | 0.17 | 3.67 | 54 | 12 |
| Ellis *et al*. (2007) - 2b | 0.171 | 0.218 | 0.49 | 66.25 | 0.29 | 4.25 | 95.46 | 0.16 | 14.26 | 60 | 13 |
| Moraes *et al*. (2014) S-SIM AL | 0.583 | 0.429 | 0.55 | 58.15 | 11.64 | 31.03 | 59.23 | 0.35 | 7.16 | 60 | 14 |
| Ellis *et al*. (2007) - 14b | 0.178 | 0.325 | 0.63 | 67.12 | 13.22 | 1.71 | 85.08 | 0.14 | 3.68 | 62 | 15 |
| Ricci *et al*. (2013) - SIM GEI | 0.548 | 0.261 | 0.48 | 66.35 | 5.33 | 9.72 | 84.95 | 0.10 | 11.97 | 68 | 16 |
| Ricci *et al*. (2013) - DMI | 0.156 | 0.229 | 0.46 | 67.62 | 5.01 | 6.51 | 88.47 | 0.07 | 12.72 | 73 | 17 |
| Ellis *et al*. (2009) - W | 0.262 | 0.203 | 0.38 | 68.11 | 5.37 | 12.52 | 82.11 | 0.13 | 11.22 | 81 | 18 |
| Ellis *et al*. (2009) - P | 0.049 | 0.244 | 0.64 | 75.29 | 19.21 | 0.36 | 80.43 | -0.06 | 2.49 | 88 | 19 |
| Moraes *et al*. (2014) H-DL | 0.752 | 0.649 | 0.72 | 32.79 | 59.26 | 27.87 | 12.87 | -0.50 | 0.31 | 92 | 20 |
| Ellis *et al*. (2007) - 1b | 0.288 | 0.287 | 0.51 | 74.16 | 31.33 | 3.24 | 65.44 | -0.05 | 2.13 | 94 | 21 |
| Ellis *et al*. (2009) - O | 0.052 | 0.252 | 0.65 | 76.14 | 21.03 | 0.63 | 78.34 | -0.08 | 2.23 | 96 | 22 |
| Ellis *et al.* (2009) - D | 0.321 | 0.143 | 0.24 | 68.84 | 2.10 | 23.95 | 73.95 | 0.11 | 28.96 | 97 | 23 |
| Ellis *et al*. (2009) - V | 0.338 | 0.119 | 0.20 | 69.78 | 2.64 | 27.20 | 70.16 | 0.09 | 28.86 | 106 | 24 |
| Ellis *et al*. (2009) - W2 | -0.012 | 0.196 | 0.64 | 78.08 | 18.38 | 2.06 | 79.56 | -0.14 | 2.39 | 106 | 25 |
| Ellis *et al*. (2009) - W1 | -0.003 | 0.219 | 0.69 | 78.34 | 18.66 | 3.06 | 78.28 | -0.15 | 2.13 | 107 | 26 |
| Moraes *et al.* (2014) H-GEL | 0.809 | 0.544 | 0.60 | 43.99 | 66.75 | 26.97 | 6.29 | -1.70 | 0.20 | 109 | 27 |
| Ellis *et al*. (2007) - 11b | 0.155 | 0.278 | 0.60 | 78.96 | 34.11 | 0.05 | 65.84 | -0.19 | 1.55 | 110 | 28 |
| Ellis *et al*. (2009) - Q | 0.066 | 0.028 | 0.09 | 75.93 | 9.92 | 6.52 | 83.56 | -0.08 | 9.14 | 110 | 29 |
| Ellis *et al*. (2007) - 13b | 0.128 | 0.208 | 0.44 | 76.45 | 27.95 | 2.49 | 69.56 | -0.11 | 2.46 | 112 | 30 |

AL, animal level; DL, dietary level; GE, gross energy (MJ/kg DM); GEI, gross energy intake (MJ/d); GEL, gross energy level; H, heifers; S, steers; SIM, calculated.

**Supplementary Material S1: References**

Boadi DA, Wittenberg KM and McCaughey WP 2001. Effects of grain supplementation on methane production of grazing steers using the sulphur (SF6) tracer gas technique. Canadian Journal of Animal Science 82, 151-157.

Boadi DA and Wittenberg KM 2002. Methane production from dairy and beef heifers fed forages differing in nutrient density using the sulphur hexafluoride (SF6) tracer gas technique. Canadian Journal of Animal Science 82, 201-206.

Boland TM, Quinlan C, Pierce KM, Lynch MB, Kenny DA, Kelly AK and Purcell PJ 2013. The effect of pasture pregrazing herbage mass on methane emissions, ruminal fermentation, and average daily gain of grazing beef heifers. Journal Animal Science 91, 3867-3874.

Chung YH, McGeough EJ, Acharya S, McAllister TA, McGinn SM, Harstad OM and Beauchemin KA 2013. Enteric methane emission, diet digestibility, and nitrogen excretion from beef heifers fed sainfoin or alfalfa. Journal Animal Science 91, 4861–4874.

Chung YH, Walker ND, McGinn SM and Beauchemin KA 2011. Differing effects of 2 active dried yeast *(Saccharomyces cerevisiae*) strains on ruminal acidosis and methane production in nonlactating dairy cows. Journal Dairy Science 94, 2431-2439.

Cooprider KL, Mitloehner FM, Famula TR, Kebreab E, Zhao Y and Van Eenennaam AL 2011. Feedlot efficiency implications on greenhouse gas emissions and sustainability. Journal Animal Science 89, 2643-2656.

Doreau M, van der Werf HMG, Micol D, Dubroeucq H, Agabriel J, Rochette Y and Martin C 2011. Enteric methane production and greenhouse gases balance of diets differing in concentrate in the fattening phase of a beef production system. Journal Animal Science 89, 2518-2528.

Dos Santos Pedreira M, Berchelli TT, Primavesi O, de Oliveira SG, Frighetto R and de Lima MA 2012. Influence of different supplements and sugarcane (*Saccharum officinarum* L.) cultivars on intake, digestible variables and methane production of dairy heifers under tropical conditions. Tropical Animal Health and Production 44, 1773-1778.

Fiorentini G, Carvalho IPC, Messana JD, Castagnino PS, Berndt A and Canesin RC 2014. Effect of lipid sources with different fatty acid profiles on the intake, performance, and methane emissions of feedlot Nellore steers. Journal Animal Science 92, 1613-1620.

Fitzsimons C. Kenny DA, Deighton MH, Fahey AG and McGee M 2013. Methane emissions, body composition, and rumen fermentation traits of beef heifers differing in residual feed intake. Journal Animal Science 91, 1-14.

Grainger C, Clarke T, Beauchemin KA, McGinn SM and Eckard RJ 2008. Supplementation with whole cottonseed reduces methane emissions and can profitably increase milk production of dairy cows offered a forage and cereal grain diet. Australian Journal Experimental Agricultural 48, 73-76.

Gutierrez–Bañuelos H, Anderson RC, Carstens GE, Slay LJ, Ramlachan N, Horrocks SM, Callaway TR, Edrington TS and Nisbet DJ 2007. Zoonotic bacterial populations, gut fermentation characteristics and methane production in feedlot steers during oral nitroethane treatment and after the feeding of an experimental chlorate product. Anaerobe 13, 21-31.

Hales KE, Cole NA and MacDonald JC 2012. Effects of corn processing method and dietary inclusion of wet distillers grains with solubles on energy metabolism, carbon–nitrogen balance, and methane emissions of cattle. Journal Animal Science 90, 3174-3185.

Hales KE, Cole NA and MacDonald JC 2013. Effects of increasing concentrations of wet distillers grains with solubles in steam–flaked, corn–based diets on energy metabolism, carbon–nitrogen balance, and methane emissions of cattle. Journal Animal Science 91, 819-828.

Hales KE, Brown–Brandl TM and Freetly HC 2014a. Effects of decreased dietary roughage concentration on energy metabolism and nutrient balance in finishing beef cattle. Journal Animal Science 92, 264-271.

Hales KE, Foote AP, Brown–Brandl TM and Freetly HC 2014b. Effects of dietary glycerin inclusion at 0, 5, 10, and 15 of dry matter on energy metabolism and nutrient balance in finishing beef steers. Journal Animal Science 93, 348-356.

Hart KJ, Martin PG, Foley PA, Kenny DA and Boland TM 2009. Effect of sward dry matter digestibility on methane production, ruminal fermentation, and microbial populations of zero–grazed beef cattle. Journal Animal Science 87, 3342-3350.

Henry DD, Ruiz-Moreno M, Ciriaco FM, Kohmann M, Mercadante VRG, Lamb GC and DiLorenzo N. Effects of chitosan on nutrient digestibility CH4 emissions, and in vitro fermentation in beef cattle. Journal Animal Science 93, 3539-3550

Hegarty RS, Goopy JP, Herd RM and McCorkell B 2007. Cattle selected for lower residual feed intake have reduced daily methane production. Journal Animal Science 85, 1479-1486.

Hosoda, K., Miyaji, M., Matsuyama, H., Imai, Y., Nonaka, K., 2012. Digestibility, ruminal fermentation, nitrogen balance and methane production in Holstein steers fed diets containing soy sauce cake at 10 or 20. Anim. Sci. J. 83, 220–226.

Hulshof RBA, Berndt A, Gerrits WJJ, Dijkstra J, van Zijderveld SM, Newbold JR and Perdok HB 2012. Dietary nitrate supplementation reduces methane emission in beef cattle fed sugarcane–based diets. Journal Animal Science 90, 2317-2323.

Hünerberg M, McGinn SM, Beauchemin KA, Okine EK, Harstad OM and McAllister TA 2013a. Effect of dried distillers grains plus solubles on enteric methane emissions and nitrogen excretion from growing beef cattle. Journal Animal Science 91, 2846-2857.

Hünerberg M, McGinn SM, Beauchemin KA, Okine EK, Harstad OM and McAllister TA 2013b. Effect of dried distillers grains with solubles on enteric methane emissions and nitrogen excretion from finishing beef cattle. Canadian Journal Animal Science 93, 373-385.

Jiao HP, Yan T, McDowell DA, Carson AF, Ferris CP, Easson DL and Wills D 2013. Enteric methane emissions and efficiency of use of energy in Holstein HS at age of six months. Journal Animal Science 91, 356-362.

Jones FM, Phillips FA, Naylor T and Mercer NB 2011. Methane emissions from grazing Angus beef cows selected for divergent residual feed intake. Animal Feed Science Technology 166–167, 302-307.

Jordan E, Lovett DK, Monahan FJ, Callan J, Flynn B and O'Mara FP 2006a. Effect of refined coconut oil or copra meal on methane output and on intake and performance of beef heifers. Journal Animal Science 84, 162-170.

Jordan E, Kenny D, Hawkins M, Malone R, Lovett DK and O'Mara FP 2006b. Effect of refined soy oil or whole soybeans on intake, methane output, and performance of young bulls. Journal Animal Science 84, 2418-2425.

Lee C, Araujo RC, Koenig KM and Beauchemin KA 2015. Effects of encapsulated nitrate on eCH4 production and nitrogen and energy utilization in beef heifers. Journal Animal Science 93, 2405-2418

Li W and Powers W 2012. Effects of saponin extracts on air emissions from steers. Journal Animal Science 90, 4001-4013.

Lila Z, Mohammed N, Kanda S, Kurihara M and Itabashi H 2005. Sarsaponin effects on ruminal fermentation and microbes, methane production, digestibility and blood metabolites in steers. Asian–Aust. Journal Animal Science 8, 1746-1751.

Lovett D, Lovell S, Stack L, Callan J, Finlay M, Conolly J and O’Mara FP 2003. Effect of forage/concentrate ratio and dietary coconut oil level on methane output and performance of finishing beef heifers. Livestock Production Science 84, 1-12.

Mc Geough EJ, O'Kiely P, Foley PA, Hart KJ, Boland TM and Kenny DA 2010a. Methane emissions, feed intake, and performance of finishing beef cattle offered maize silages harvested at 4 different stages of maturity. Journal Animal Science 88, 1479-1491.

Mc Geough, EJ, O'Kiely P, Hart KJ, Moloney AP, Boland TM and Kenny DA 2010b. Methane emissions, feed intake, performance, digestibility, and rumen fermentation of finishing beef cattle offered whole–crop wheat silages differing in grain content. Journal Animal Science 88, 2703-2716.

McGinn SM, Chung YH, Beauchemin KA, Iwaasa AD and Grainger C 2009. Use of corn distillers’ dried grains to reduce enteric methane loss from beef cattle. Canadian Journal Animal Science 89, 409-413.

Molano G, Clark H, Knight TW and Cavanagh A 2006. Methane emissions from growing beef cattle grazing hill country pasture. Proceedings New Zealand Society Animal Production 66, 172-175.

Newbold JR, van Zijderveld SM, Hulshof RBA, Fokkink WB, Leng RA, Terencio P, Powers WJ, van Adrichem PSJ, Paton ND and Perdok HB 2014. The effect of incremental levels of dietary nitrate on methane emissions in Holstein steers and performance in Nelore bulls. Journal Animal Science 92, 5032-5040.

Pinares–Patiño CS, Baumont R and Martin C 2003. Methane emissions by Charolais cows grazing a monospecific pasture of timothy at four stages of maturity. Canadian Journal Animal Science 83, 769-777.

Romero–Perez A, Okine EK, McGinn SM, Guan LL, Oba M, Duval SM, Kindermann M, and Beauchemin KA 2014. The potential of 3–nitrooxypropanol to lower enteric methane emissions from beef cattle. Journal Animal Science 92, 4682-4693.

Romero–Perez A, Okine EK, McGinn SM, Guan LL, Oba M, Duval SM, Kindermann M and Beauchemin KA 2015. Sustained reduction in methane production from long–term addition of 3–nitrooxypropanol to a beef cattle diet. Journal Animal Science 93, 1780-1791.

Stackhouse–Lawson KR, Calvo MS, Place SE, Armitage TL, Pan Y, Zhao Y and Mitloehner FM 2013. Growth promoting technologies reduce greenhouse gas, alcohol, and ammonia emissions from feedlot cattle. Journal Animal Science 91, 5438-5447.

Stackhouse KR, Pan Y, Zhao Y and Mitloehner FM 2011. Greenhouse gas and alcohol emissions from feedlot steers and calves. Journal Environmental Quality 40, 899-906.

Staerfl SM, Zeitz JO, Kreuzer M and Soliva CR 2012. Methane conversion rate of bulls fattened on grass or maize silage as compared with the IPCC default values, and the long–term methane mitigation efficiency of adding acacia tannin, garlic, maca and lupine. Agricultural Ecosystem Environmental 148, 111-120.

Troy SM, Duthie C-A, Hyslop JJ, Roehe R, Ross DW, Wallace RJ, Waterhouse A and Rooke JA 2015. Effectiveness of nitrate addition and increased oil content as methane mitigation strategies for beef cattle fed two contrasting basal diets. Journal Animal Science 93, 1815-1823

Vyas D, McGeough EJ, McGinn SM, McAllister TA and Beauchemin KA 2014. Effect of *Propionibacterium* spp. on ruminal fermentation, nutrient digestibility, and methane emissions in beef heifers fed a high–forage diet. Journal Animal Science 92, 2192-2201.

Vyas D, McGeough EJ, Mohammed R, McGinn SM, McAllister TA and Beauchemin KA 2014. Effect of *Propionibacterium* spp. on ruminal fermentation, nutrient digestibility, and methane emissions in beef cattle fed a corn grain finishing diets. Animal 8, 1807-1815.

Vyas D, Alazzeh A, McGinn SM, McAllister TA, Harstad OM, Holo H and Beauchemin KA 2015. Enteric methane emissions in response to ruminal inoculation of *Propionibacterium* strains in beef cattle fed a mixed diet. Animal Production Science. Journal Compilation 2015. A–F.