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# Relationship between carbon dioxide production and performance in cattle and pigs

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## Abstract

An extensive number of metabolic experiments have been carried out at the former Oskar-Kellner-Institute, now the ›Oskar Kellner‹ Research Unit of Nutritional Physiology at the Research Institute for the Biology of Farm Animals (FBN), Dummerstorf, on cattle, pigs and humans. Their expired amounts of $CO_2$ having been compiled and stratified with regard to various performance and nutrition levels. The annual $CO_2$ emission of a 700 kg cow with an annual milk yield of 10 000 kg has been estimated to be 4.7 t. With increasing food intake and performance, a concomitant increase of $CO_2$ production per time unit has been observed. However, with increasing performance, we have determined a strong decrease of $CO_2$ output per mass unit of animal-derived food (i.e. meat and milk). This decrease amounts to 40% when comparing cows with 4 000 kg and 8 000 kg annual milk yields. The $CO_2$ emission per kg dry matter (DM) intake amounts to 0.55 kg and is relatively constant, irrespective of live weight and performance. According to this, the world cattle livestock of 1.3 thousand million (UK)/billion (US) individuals produce 6% of the total yearly $CO_2$ emission of 30 thousand million (UK)/ billion (US) t. Similarly, in pigs, increasing daily weight gains of an additional 200 g result in a reduction of 10-15% of $CO_2$ emissions. Sows produce 1.5-1.7 kg $CO_2$ daily; fattening pigs and humans each produce 1 kg $CO_2$.

**Keywords:** $CO_2$ production, dairy cattle, bulls, swine, food intake, performance level, human

## Zusammenfassung

### Zusammenhang zwischen Kohlendioxidproduktion und Leistung bei Rind und Schwein

Aus dem umfangreichen Fundus der im Oskar-Kellner-Institut, seit 1992 ein Forschungsbereich des FBN Dummerstorf, durchgeführten Gesamtstoffwechselversuche wurden die mit den Atemgasen von Rind, Schwein und Mensch bei verschiedenen Leistungen und unterschiedlicher Ernährung abgegebenen $CO_2$-Mengen zusammengestellt. Dabei wurde ein Anstieg der $CO_2$-Produktion mit ansteigender Nahrungsaufnahme und zunehmender Leistung in der Zeiteinheit aufgezeigt. Es konnte aber auch ein starker Rückgang in der $CO_2$-Abgabe je Masseeinheit erzeugtes Produkt mit ansteigender Leistung nachgewiesen werden. Dieser Rückgang betrug beim Vergleich der Jahresleistungen von 4 000 und 8 000 kg Milch 40%. Unabhängig von der Lebendmasse und Leistung der Kühe blieb die $CO_2$-Emission je kg verzehrter Trockensubstanz bei 0,55 kg relativ konstant. Danach sind die weltweit lebenden 1,3 Milliarden Rinder mit 6% an der jährlich freigesetzten $CO_2$-Menge von ca. 30 Milliarden t beteiligt. Auch bei Schweinen bestätigt sich der Trend, dass bei

200 g höheren Tageszunahmen die $CO_2$-Abgabe um 10-15% sinkt. Zuchtsauen gaben täglich 1,5-1,7 kg $CO_2$ und Mastschweine ebenso wie der Mensch 1 kg $CO_2$ ab.

**Schlüsselwörter:** $CO_2$-Produktion, Milchvieh, Aufzuchtrinder, Mastbullen, Sauen, Mastschweine, Futteraufnahme, Leistungsniveau, Mensch

## Introduction

In the global discussion about climate change, the reduction of the current carbon dioxide ($CO_2$) released into the atmosphere stands in the spotlight of public interest. Increasing $CO_2$ concentrations are the largest source of global warming. According to the annual review of the World Meteorological Organization in Geneva, $CO_2$ contributes to 63% of the greenhouse effect, based on an annual increase in emissions of about 25 to 28 thousand million (UK)/ billion (US) t from 2000 to 2005. The main cause is the massive and partly wasteful use of energy sources such as coal, petroleum and natural gas by the human population during the past 50 years (IPCC Report 2007).

$CO_2$ represents one of the trace gases in the atmosphere with a share of 0.03%, in contrast to 77.1% nitrogen and 20.8% oxygen. In addition, air contains 1.1% hydrogen, 0.9% argon and 0.1% trace gases, including 0.03% of $CO_2$. An increase of $CO_2$ to 0.04% is assumed.

Notwithstanding this small proportion, $CO_2$ is of fundamental importance to life on earth, because glucose, starch, cellulose and other organic sources of energy and materials arise from $CO_2$ and water through photosynthesis via the exposure of chlorophyll to light energy. Therefore, in this context, $CO_2$ can be considered as a plant nutrient.

Together with the current classification of the involvement of $CO_2$ in global warming, the role of sunspot activity, natural cloud cover and water vapour are being evaluated and classified as other influential factors (IPCC Report 2007).The aim of this work has been to estimate the $CO_2$ production of our two most important livestock animals, viz. cattle and pigs, and also from humans on the basis of experimental data similar to those obtained for heat (JENTSCH *et al.* 2001) and methane (JENTSCH *et al.* 2007) production.

## Material and methods

Because of the technical effort involved, precise measurements of $CO_2$ production have been carried out worldwide in only a few institutes and are unlikely to be carried out in the future with the same complexity and form as described in this report. One of these institutes, the Oskar Kellner Institute (OKI), which was founded by K. Nehring in 1953 and further supported by the Rostock group of scientists including R. Schiemann, L. Hoffmann and W. Jentsch, has belonged since 1970 as a research unit to the Research Centre at Dummerstorf and, from 1992, has been known as the Research Unit of Nutritional Physiology ›Oskar Kellner‹ at the FBN Dummerstorf.

The investigation of this problem has taken into account those factors that influence metabolism and thus $CO_2$ production, such as the nutrient composition of the diet and nutritional and performance levels. These are the same factors that determine energy requirements and have been used for the calculation of energy requirements.

The values of $CO_2$ production are means from 4-5-day periods. The data for dairy cows are based on 198 total metabolic periods the results of which have been published in several reports, but without a direct description of the $CO_2$ production values. Results for maintenance energy requirements and energy utilization for milk production (SCHIEMANN *et al.* 1970), for energy utilization at various performance levels or during lactation (HOFFMANN *et al.* 1972), for utilization of body energy for milk production from measurements during 26 periods (SCHIEMANN *et al.* 1974) and for other aspects have been used for the derivation of energy standards for cows (HOFFMANN *et al.* 1974). These results essentially agree with those in the literature (FLATT *et al.* 1969, VAN ES and NIJKAMP 1969).

Using heifers (rearing cattle), we carried out (SCHIEMANN *et al.* 1987) 6 series of experiments involving different rates of growth of the young cattle and at different ages at their first calving; these results formed the basis for the formulation of energy standards (HOFFMANN *et al.* 1988, HOFFMANN and JENTSCH 1988).

With young bulls, 14 trials were carried out at high production levels (SCHIEMANN *et al.* 1976) and further experiments with lower body weight gains (JENTSCH *et al.* 1977, 1978, WITTENBURG *et al.* 1976). On the basis of these experiments and the results of the performance testing of bulls of various breeds (BLISCHKE 1978), improved energy standards were obtained (HOFFMANN *et al.* 1981) and published as the revised Rostock feed evaluation system (JENTSCH *et al.* 2004).

In order to improve the energy standards of pregnant and lactating sows, nine trials were carried out with sows in various reproductive cycles and receiving various energy supplies (BEYER *et al.* 1994, 1995). These results formed the basis for the derivation of the requirement standards for sows (HOFFMANN *et al.* 1990).
Experiments with Landrace pigs (JENTSCH and HOFFMANN 1977) and with hybrid pigs (JENTSCH *et al.* 1983) raised under various feeding regimes were used to calculate the requirement standards (HOFFMANN *et al.* 1979, 1983, JENTSCH *et al.* 2004).

For all measurements of energy turnover and calculations, the following units were used (HOFFMANN and SCHIEMANN 1980) – $CO_2$: 1.964 g/l, 1 l=0.509 g; $CH_4$: 0.716 g/l, 39.57 kJ/l; $O_2$: 1.428 g/l; C-content: protein 52.00 %, fat 76.70 %, carbohydrates 44.45 %.
Calculation of heat production (HP) for volumetric measurement of gas exchange (BROUWER 1965):

$$HP=16.19\cdot O_2+5.02\cdot CO_2-2.17\cdot CH_4-5.99\cdot \text{urinary N-} \quad (1)$$

The comprehensive presentation of the $CO_2$ formation of animals at different production levels was similar to the approach in the report on HP of dairy cows (JENTSCH *et al.* 2001). The calculations were not based on individual measurements, but generalized derivations for energy requirements were used. Thus, the $CO_2$ emissions were estimated by taking into account the partial coefficients of utilization for different production levels.

The data were recalculated from energy standards derived from results that were evaluated by a commission under the supervision of L. Hoffmann. The energy standards were derived after statistical processing of the experimental data.

The energy requirements are given as a net energy retention, according to the main animal species and different performance levels (JENTSCH *et al.* 2004). Based on these values, the recalculation will be demonstrated in two examples.

Example 1: $CO_2$ production during lactation

1 kg ECM (energy corrected milk, milk with 4% fat), energy requirement = 2.99 MJ net energy retention (NER), with a utilization of metabolizible energy (ME) for milk production of 62%, ME results to 4.82 MJ, difference = 1.83 MJ HP per kg ECM.
Because, in agricultural animal husbandry, the feeding level is higher, a respiratory quotient (RQ) of 1.0 to 1.3 can be assumed. According to the equation for calculating HP, we then obtain, for 1 000 kJ HP, 93-112 g $CO_2$. Per kg milk, 1.83 · 106 = 194 g $CO_2$ will be exhaled when a RQ = 1.2 is assumed. At maintenance feeding, a RQ of 0.85 is assumed.

Although not important for this problem, we should mention that 10-12% of the total $CO_2$ exhaled arises from $CO_2$ produced by rumen fermentation.

Example 2: $CO_2$ production in the pig

Fattening pig, 100 kg BW (body weight), 700 g BW gain, energy requirement = 27.2 MJ NER, with a utilization of ME for growth of 70%, ME results to 38.9 MJ, difference = 11.7 MJ of HP per animal and day at a RQ of 1.30, 11.7 · 112 g $CO_2$ = 1 310 g $CO_2$ per animal and day.

The $CO_2$ emissions from various animal categories and production levels were calculated according to the examples given above. The lower emissions at high production levels in early lactation resulting from the utilization of body energy for milk production were not taken into account because body mass has to be recovered after the end of lactation

## Results and discussion

### *$CO_2$ production by adult cattle on maintenance feeding*

The values in Table 1 should be seen as starting values if, for example, $CO_2$ emissions for milk production are to be calculated as the sum of maintenance feeding and feeding for milk production. At the maintenance level, the ME (e.g. 28 MJ NER in bovines [NERb] corresponds at 55% utilization to 51 MJ ME) equals HP and yields (RQ=0.85) 4.18 kg of $CO_2$. The increase in $CO_2$ production parallels the higher feed intake of heavier animals, whereby per 1 kg/DM intake, the $CO_2$ production is equal to 0.63 kg. The DM intake values of cows were based on information provided by PIATKOWSKI *et al.* (1990), which were also used in the following.

Table 1
Daily $CO_2$ production of adult cattle of various body weights at maintenance feeding level
*Tägliche $CO_2$-Produktion adulter Rinder mit unterschiedlicher Lebendmasse unter Erhaltungsfütterung*

| Body weight, kg | Maintenance energy requirement, MJ NERb/d | $CO_2$, kg/d | $CO_2$, kg/kg DM intake |
|---|---|---|---|
| 500 | 28 | 4.18 | 0.63 |
| 600 | 33 | 4.92 | 0.63 |
| 700 | 37 | 5.52 | 0.63 |
| 800 | 41 | 6.12 | 0.63 |

NERb net energy retention in bovines

### *$CO_2$ production during milk production*

During the production of 1 kg of milk, 194 g of $CO_2$ will be formed, as shown in Example 1. From this, multiples for $CO_2$ production are listed in Table 2.

Table 2
Daily $CO_2$ production during milk production at various performance levels without consideration of maintenance requirement
*Tägliche $CO_2$-Produktion bei der Milchbildung bei unterschiedlichem Leistungsniveau ohne Berücksichtigung des Erhaltungsbedarfs*

| Milk (ECM), kg/d | Energy requirement, MJ NERb | $CO_2$, kg/d |
|---|---|---|
| 10 | 30 | 1.95 |
| 20 | 60 | 3.90 |
| 30 | 90 | 5.85 |
| 40 | 120 | 7.80 |
| 50 | 150 | 9.75 |

NERb net energy retention in bovines

With these values and those from in Table 1, column 3, the $CO_2$ emission from maintenance and milk production can be calculated (Table 3)

Table 3
Daily $CO_2$ production of cows as affected by body weight and milk yield, and $CO_2$ production per kg feed DM
*Tägliche $CO_2$-Produktion von Kühen in Abhängigkeit von Lebendmasse und Tagesmilchleistung und $CO_2$-Produktion je kg Futter-Trockensubstanz*

| Milk (ECM), kg/d | kg $CO_2$/d from milk + maintenance | | | | kg $CO_2$ per kg feed DM | | | |
|---|---|---|---|---|---|---|---|---|
| | 500 kg BW | 600 kg BW | 700 kg BW | 800 kg BW | 500 kg BW | 600 kg BW | 700 kg BW | 800 kg BW |
| 10 | 6.13 | 6.87 | 7.47 | 8.07 | 0.53 | 0.55 | 0.55 | 0.55 |
| 20 | 8.08 | 8.82 | 9.42 | 10.02 | 0.54 | 0.55 | 0.55 | 0.56 |
| 30 | 10.03 | 10.77 | 11.37 | 11.97 | 0.55 | 0.56 | 0.56 | 0.56 |
| 40 | – | 12.72 | 13.32 | 13.92 | – | 0.56 | 0.56 | 0.56 |
| 50 | – | – | 15.27 | 15.87 | – | – | (0.56) | (0.56) |

The $CO_2$ production per day increases with milk yield (Table 3) but, per kg DM intake, only small changes in a narrow range of 0.53-0.56 kg occur. The two values of 0.56 in the last line of Table 3 are given in parentheses because, at this stage, the milk is formed partly from body energy.

Table 4
$CO_2$ production per kg milk at various performance and body weight levels
*Die $CO_2$-Abgabe je kg produzierte Milch bei unterschiedlicher Milchleistung und Lebendmasse*

| Milk (ECM), kg/d | $CO_2$ emission per kg of produced milk, kg | |
|---|---|---|
| | 600 kg BW | 800 kg BW |
| 10 | 0.7 | 0.8 |
| 20 | 0.44 | 0.5 |
| 30 | 0.36 | 0.4 |
| 40 | 0.32 | 0.35 |
| 50 | – | 0.32 |

The $CO_2$ emission per kg of milk significantly decreases with increasing milk yield (Table 4). For 40 kg of milk per day, the $CO_2$ output per kg of milk amounts only to 40-45% of the level at 10 kg milk.

In the discussion on results of the various, sometimes contradictory, experimental results regarding the development of $CO_2$ »footprints«, a decrease in $CO_2$ output per kg of milk with increasing milk yield has been suggested (FLACHOWSKY 2008). This decrease is now established by the data in Table 4.

The distinction between conventional and ecological production is irrelevant, if only the emissions from the animals are considered. Here, the presented performance-related dependencies are valid. The higher emissions during ecological production because of lower yields are partially compensated by the reduced use of technology or the use of lower quantities of complementary or supplementary feed. In the present publication, only the animal-related $CO_2$ emissions are analysed.

The $CO_2$ production in the dry period is shown in Table 5.

Table 5
$CO_2$ production of cows at 600 kg body weight during the dry period
*Die $CO_2$-Produktion in der Trockenstehzeit bei Kühen mit 600 kg Lebendmasse*

| Days before calving | ER, MJ NERb | $CO_2$, kg/d | | | $CO_2$, kg | |
|---|---|---|---|---|---|---|
| | | maintenance, 1 | conception, 2 | 1+2 | during the period | during 60 days |
| 60-41 | 46 | 4.9 | 7.1 | 12.0 | 240 | |
| 40-21 | 56 | 4.9 | 12.5 | 17.4 | 350 | |
| 20-1 | 58 | 4.9 | 13.6 | 18.5 | 370 | 960 |

ER energy requirement, NERb net energy retention in bovines

The partition into »maintenance« and »conception« is useful as it takes into account the low utilization of ME for the formation of conception products by 15-20% attributable to the increasing maintenance requirement in this period.

Table 6
Annual $CO_2$ production as affected by milk performance and body weight, dry period included
*Jährliche $CO_2$-Produktion in Abhängigkeit von der Milchleistung und Lebendmasse, einschließlich Trockenperiode*

| Annual performance, kg milk/a (ECM) | Annual $CO_2$, kg | | | | $CO_2$, kg/kg milk* |
|---|---|---|---|---|---|
| | 500 kg BW | 600 kg BW | 700 kg BW | 800 kg BW | |
| 4 000 | 2 985 (100) | 3 255 (100) | 3 475 (100) | 3 695 (100) | 0.87 |
| 6 000 | 3 345 (112) | 3 615 (111) | 3 835 (110) | 4 055 (110) | 0.64 |
| 8 000 | 3 765 (126) | 4 035 (124) | 4 255 (122) | 4 480 (121) | 0.53 |
| 10 000 | – | 4 460 (137) | 4 675 (135) | 4 895 (132) | 0.47 |
| 12 000 | – | – | 5 040 (145) | 5 260 (142) | 0.42 |

* calculated for cows with 700 kg BW, Values in parenthesis are related to values in the top row.

The values in Table 6 for the $CO_2$ production of the cows are the sum of $CO_2$ emissions in the lactation and dry periods. The body-weight-related differences in the dry period also are taken into account. As an example, the $CO_2$ production of a 700-kg cow with a milk yield of 4 000 or 8 000 kg increases from 3.48 to 4.26 tons, i.e. by 20%. In contrast, the $CO_2$ production per kg of milk decreases significantly from 0.87 to 0.53 kg per kg milk, i.e. by 40%.

### *$CO_2$ production of young female cattle and fattening bulls*

For heifers and fattening bulls, the $CO_2$ production increases with increasing body weight of the animals and the gain in body weight but decreases with increasing daily gain in body weight (Table 7).

Table 7
$CO_2$ production of heifers and young fattening bulls in kg per day, kg per kg body weight gain, and kg per kg dry matter intake depending on body weight and daily gain
*Die $CO_2$-Produktion weiblicher Jungrinder und von Mastbullen in Abhängigkeit von Lebendmasse und Lebendmassezunahme (LMZ) je Tier und Tag, je kg LMZ und je kg Trockensubstanzaufnahme*

| BW, kg | BWG, g | ER, MJ NERb | $CO_2$ production | | |
|---|---|---|---|---|---|
| | | | kg/d | kg/kg BWG | kg/kg DMI |
| *Heifers* | | | | | |
| 200 | 400 | 21.0 | 1.65 | 4.12 | 0.38 |
| | 600 | 25.7 | 2.10 | 3.50 | 0.42 |
| | 800 | 31.0 | 2.61 | 3.26 | 0.48 |
| 300 | 400 | 29.4 | 2.31 | 5.78 | 0.37 |
| | 600 | 35.7 | 2.92 | 4.87 | 0.44 |
| | 800 | 44.6 | 3.76 | 4.70 | 0.54 |
| 400 | 400 | 37.8 | 2.97 | 7.43 | 0.50 |
| | 600 | 43.6 | 3.57 | 5.95 | 0.42 |
| | 800 | 49.4 | 4.16 | 5.20 | 0.50 |
| 500 | 400 | 42.0 | 3.30 | 8.25 | 0.42 |
| | 600 | 48.3 | 3.95 | 6.58 | 0.47 |
| | 800 | 54.1 | 4.56 | 5.70 | 0.50 |
| *Fattening bulls* | | | | | |
| 200 | 800 | 24.7 | 2.08 | 2.60 | 0.47 |
| | 1 000 | 26.8 | 2.32 | 2.32 | 0.50 |
| | 1 200 | 28.9 | 2.58 | 2.15 | 0.54 |
| 300 | 1 000 | 38.3 | 3.32 | 3.32 | 0.46 |
| | 1 200 | 42.0 | 3.75 | 3.12 | 0.51 |
| | 1 400 | 46.2 | 4.23 | 3.02 | 0.54 |
| 400 | 1 000 | 47.8 | 4.15 | 4.15 | 0.45 |
| | 1 200 | 52.5 | 4.68 | 3.90 | 0.50 |
| | 1 400 | 57.8 | 5.30 | 3.79 | 0.55 |
| 500 | 1 000 | 56.7 | 4.92 | 4.92 | 0.49 |
| | 1 200 | 62.5 | 5.57 | 4.64 | 0.54 |
| | 1 400 | 68.8 | 6.30 | 4.50 | 0.58 |

BWG body weight gain, ER energy requirement, NERb net energy retention in bovines, DMI dry matter intake

As shown in the last columns of both sections, the $CO_2$ output per kg DM intake in the heifers is in the range of 0.37-0.54 kg and in the fattening bulls of 0.45-0.58 kg, increasing with increasing daily body weight gain. For non-lactating cows, we calculated a value of 0.6 kg, and for lactating cows of 0.5-0.6 kg. The difference between the heifers and fattening bulls is attributable to the different performance levels. Higher daily gains of 800 g compared with 400 g in heifers and from 1 400 g compared with 1 000 g in fattening bulls lead to 20-30 % and 10 % lower $CO_2$ emissions, respectively.

### *$CO_2$ production of breeding sows*

Pregnant and lactating sows emit 1.0-1.4 or 1.2-1.8 kg $CO_2$ per day with regard to sows differentiated by age and course of lactation (Tables 8 and 9).

Table 8
$CO_2$ production of pregnant sows
*Die $CO_2$-Produktion trächtiger Sauen*

| Number of pregnancy | Day of pregnancy | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1-84 | | | 85-105 | | | 106-115 | | |
| | BW, kg | NERs, MJ | $CO_2$, kg/d | BW, kg | NERs, MJ | $CO_2$, kg/d | BW, kg | NERs, MJ | $CO_2$, kg/d |
| 1 | 150 | 22.1 | 1.00 | 180 | 25.0 | 1.12 | 190 | 28.7 | 1.28 |
| 2 | 180 | 24.3 | 1.09 | 210 | 25.7 | 1.15 | 220 | 29.4 | 1.31 |
| 3 | 200 | 25.0 | 1.12 | 225 | 26.5 | 1.18 | 235 | 30.1 | 1.35 |
| 4-8 | 220 | 25.0 | 1.12 | 240 | 27.2 | 1.22 | 250 | 31.5 | 1.40 |

NERs net energy retention in swine

Per kg DM intake (these data are not included in the tables), the $CO_2$ emission of pregnant sows amounts to 0.35 kg at the beginning of pregnancy and to 0.43 kg at the end. This is correlated with the decreased utilization of feed and/or the increasing maintenance energy requirement at the end of pregnancy. The lactating sows emit uniformly 0.34 kg of $CO_2$ per kg DM intake.

Table 9
$CO_2$ production of lactating sows
*Die $CO_2$-Produktion laktierender Sauen*

| Number of lactation | BW, kg | Week of lactation | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3-6 | | 7 | |
| | | NERs, MJ | $CO_2$, kg/d | NERs, MJ | $CO_2$, kg/d | NERs, MJ | $CO_2$, kg/d | NERs, MJ | $CO_2$, kg/d |
| 1 | 175 | 34.5 | 1.20 | 39.0 | 1.35 | 42.6 | 1.50 | 39.0 | 1.35 |
| 2 | 200 | 44.1 | 1.55 | 50.0 | 1.75 | 50.0 | 1.75 | 46.3 | 1.65 |
| 3 | 215 | 45.6 | 1.60 | 51.4 | 1.80 | 51.4 | 1.80 | 47.8 | 1.70 |
| 4-8 | 230 | 42.6 | 1.50 | 47.8 | 1.70 | 51.4 | 1.80 | 47.0 | 1.65 |

NERs net energy retention in swine

The $CO_2$ production of lactating sows in the 8th lactation week approximates that in the 1st lactation week.

### *$CO_2$ production of fattening pigs*

In fattening pigs, the differentiation of body weight and the increase in body weight is reflected in $CO_2$ production. Higher body weight gains lead to lower $CO_2$ emissions per kg gain and, on the basis of per kg feed intake, they are equal at about 0.46–0.48 kg.

Table 10
$CO_2$ production of fattening pigs
*Die $CO_2$-Produktion von Mastschweinen*

| BW, kg | BWG, g | ER, MJ NERs | $CO_2$ production | | |
|---|---|---|---|---|---|
| | | | kg/d | kg/kg BWG | kg/kg DMI |
| 40 | 500 | 14.0 | 0.67 | 1.34 | 0.46 |
| | 700 | 18.4 | 0.88 | 1.26 | 0.46 |
| 60 | 400 | 15.4 | 0.74 | 1.85 | 0.46 |
| | 600 | 19.8 | 0.95 | 1.58 | 0.46 |
| | 800 | 24.3 | 1.17 | 1.46 | 0.47 |
| 80 | 400 | 17.6 | 0.85 | 2.11 | 0.48 |
| | 600 | 22.8 | 1.09 | 1.82 | 0.48 |
| | 800 | 27.9 | 1.34 | 1.67 | 0.48 |
| 100 | 500 | 22.0 | 1.06 | 2.11 | 0.48 |
| | 700 | 27.2 | 1.31 | 1.87 | 0.48 |
| 120 | 500 | 23.5 | 1.13 | 2.26 | 0.48 |
| | 700 | 29.4 | 1.41 | 2.02 | 0.48 |

BWG body weight gain, ER energy requirement, NERs net energy retention in swine, DMI dry matter intake

### *$CO_2$ production of humans*

$CO_2$ production was also measured in three trials involving men over 50 years of age (methodological aspects, JUNGHANS *et al.* 2008; determination of the utilization of starch for fat retention, JENTSCH *et al*. 2000) in respiration chambers (Table 11). In trial 1, the subjects were fasted overnight for 12 h and remained in a sitting position for 3 h in the respiration chamber. The measured values of experiments 2 and 3 were obtained in a difference trial with the person remaining in the respiration chamber three times for 23 h under similar activity programmes (eating, exercise in the chamber, sitting at a desk) on each experimental day. The basic diet in the experiment 2 covered the energy maintenance requirement with a slightly positive balance and, in experiment 3, the energy retention from the diet supplement was 5 200 kJ/ day.

Table 11
$CO_2$ production of men aged 50 years and more
*Die $CO_2$-Produktion von >50-jährigen Männern*

| Trial | Nutritional level | *n* | $CO_2$ production, kg/d |
|---|---|---|---|
| 1 | Fasting | 8 | $0.74 \pm 0.047$ |
| 2 | Maintenance | 3 | $0.81 \pm 0.055$ |
| 3 | Energy retention | 3 | $1.06 \pm 0.058$ |

During fasting, $CO_2$ production was 10% lower than under a maintenance diet; however, because of the small sample size, the values fluctuated greatly. In trial 3, $CO_2$ production was 30% higher than that in the 2nd trial. The $CO_2$ production of a man of approximately 75 kg in weight can be set to 1 kg per day, if his activity is in the medium range. With intense exercise or heavy physical work, a 20% higher output can be expected.

## Conclusions

The presented results relate to the $CO_2$ emissions resulting from nutrient and energy turnover of the food in the body of cattle and pigs. Those that occur additionally through the use of technology have not been included.

The approach chosen to estimate $CO_2$ production by using energy requirement standards ensure a higher degree of generalization in comparison with individual measurements. This is particularly true as the energy standards have been examined and confirmed under production conditions, (BLISCHKE 1978, FRANKE 1977, GUTBIER 1984). As the obtained energy standards and coefficients of utilization are compared with those in the literature, we can assume similar $CO_2$ emissions. Model calculations and comparisons of feed evaluation and standards for various species (SCHIEMANN *et al.* 1982, VAN DER HONING and STEG 1980, 1990) show good agreement.

The information obtained on the basis of experimental data in cattle is relevant on two counts: the daily $CO_2$ release of a 700 kg cow yielding 10 or 30 kg of milk increases from 7.5 to 11.4 kg but, at the same time, the $CO_2$ output per kg of milk drops by 40%. For a desired amount of milk, a higher milk production per animal requires a smaller number of animals, whereby the maintenance energy requirement is lower and, correspondingly, the release of $CO_2$ is reduced.

Thus, the negative image previously associated with the name »turbo-cows« is now repudiated and reflects the opposite of what the coiners of the word once thought.

The above results show that the $CO_2$ emission per kg of DM consumed, regardless of the performance and body weight, is relatively constant at 0.55 kg per cow. Thus, we can now provide more accurate information on the $CO_2$ release of the world's 1.3 thousand million (UK)/billion (US) young and adult cattle. Under the assumption of an average daily intake of 40 kg pasture grass (7 kg DM) per head, an average cow) would consume 2.5 tons DM per year and the entire cattle population 3.25 thousand million (UK)/billion (US) tons, leading to an annual $CO_2$ emission of approximately 1.8 thousand million (UK)/billion (US) tons, i.e. 6% of the total emission.

Furthermore, in pigs, the trend has been confirmed that an increase of 200 g in daily gain is followed by a decrease in $CO_2$ release of 10-15%. Breeding sows daily emit 1.5-1.7 kg of $CO_2$ and fattening pigs about 1 kg, i.e. the same as human with adequate nutrition.

The $CO_2$ emissions of cattle and pigs cannot be considered as an additional factor destroying the climate. As mentioned above, nutrients are formed from the trace gas $CO_2$ in the atmosphere and water by means of photosynthesis in the chlorophyll of plants. These nutrients, for instance those which are contained in grass and which are thus unusable directly by humans, are converted by the cattle into milk and meat. This conversion produces $CO_2$, which is released into the atmosphere from whence it was originally taken up. Therefore, the $CO_2$ produced during the metabolism of such plant nutrients is »emission neutral« and, in this case, does not emanate from cattle or pigs.

Furthermore, the presented results clearly show that, with increasing production levels, the $CO_2$ emissions per unit product can be drastically reduced, as has been established for methane production (JENTSCH *et al.* 2007, PIATKOWSKI 2008).

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